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(54) Title: IMMUNOGLOBULIN VARIANTS AND USES THEREOF

(57) Abstract: The invention provides humanized and chimeric anti-CD20 antibodies for treatment of CD20 positive malignancies and autoimmune diseases.

## IMMUNOGLOBULIN VARIANTS AND USES THEREOF

FIELD OF THE INVENTION

10 The invention relates to anti-CD20 antibodies and their use in the treatment of B-cell related  
diseases.

BACKGROUND OF THE INVENTION

15 Lymphocytes are one of several populations of white blood cells; they specifically recognize and respond to foreign antigen. The three major classes of lymphocytes are B lymphocytes (B cells), T lymphocytes (T cells) and natural killer (NK) cells. B lymphocytes are the cells responsible for antibody production and provide humoral immunity. B cells mature within the bone marrow and leave the marrow expressing an antigen-binding antibody on their cell surface. When a naive B cell first encounters the antigen for which its membrane-bound antibody is specific, the cell begins to divide rapidly and its progeny  
20 differentiate into memory B cells and effector cells called "plasma cells". Memory B cells have a longer life span and continue to express membrane-bound antibody with the same specificity as the original parent cell. Plasma cells do not produce membrane-bound antibody but instead produce secreted form of the antibody. Secreted antibodies are the major effector molecules of humoral immunity.

25 The CD20 antigen (also called human B-lymphocyte-restricted differentiation antigen, Bp35) is a hydrophobic transmembrane protein with a molecular weight of approximately 35 kD located on pre-B and mature B lymphocytes (Valentine *et al.* *J. Biol. Chem.* 264(19):11282-11287 (1989); and Einfeld *et al.* *EMBO J.* 7(3):711-717 (1988)). The antigen is also expressed on greater than 90% of B cell non-Hodgkin's lymphomas (NHL) (Anderson *et al.* *Blood* 63(6):1424-1433 (1984)), but is not found on hematopoietic stem cells, pro-B cells, normal plasma cells or other normal tissues (Tedder *et al.* *J. Immunol.* 135(2):973-979  
30 (1985)). CD20 is thought to regulate an early step(s) in the activation process for cell cycle initiation and differentiation (Tedder *et al.*, *supra*) and possibly functions as a calcium ion channel (Tedder *et al.* *J. Cell. Biochem.* 14D:195 (1990)).

35 Given the expression of CD20 in B cell lymphomas, this antigen has been a useful therapeutic target to treat such lymphomas. There are more than 300,000 people in the United States with B-cell NHL and more than 56,000 new cases are diagnosed each year. For example, the rituximab (RITUXAN®) antibody which is a genetically engineered chimeric murine/human monoclonal antibody directed against human CD20 antigen (commercially available from Genentech, Inc., South San Francisco, California, U.S.) is used for the treatment of patients with relapsed or refractory low-grade or follicular, CD20 positive, B cell non-Hodgkin's lymphoma. Rituximab is the antibody referred to as "C2B8" in US Patent No. 5,736,137  
40 issued April 7, 1998 (Anderson *et al.*) and in US Pat No. 5,776,456. *In vitro* mechanism of action studies have demonstrated that RITUXAN® binds human complement and lyses lymphoid B cell lines through complement-dependent cytotoxicity (CDC) (Reff *et al.* *Blood* 83(2):435-445 (1994)). Additionally, it has significant activity in assays for antibody-dependent cellular cytotoxicity (ADCC). *In vivo* preclinical studies have shown that RITUXAN® depletes B cells from the peripheral blood, lymph nodes, and bone  
45 marrow of cynomolgus monkeys, presumably through complement and cell-mediated processes (Reff *et al.*

5 *Blood* 83(2):435-445 (1994)). Other anti-CD20 antibodies indicated for the treatment of NHL include the murine antibody Zevalin™ which is linked to the radioisotope, Yttrium-90 (IDEC Pharmaceuticals, San Diego, CA), Bexxar™ which is another fully murine antibody conjugated to I-131 (Corixa, WA).

A major limitation in the use of murine antibodies in human therapy is the human anti-mouse antibody (HAMA) response (see, e.g., Miller, R.A. et al. "Monoclonal antibody therapeutic trials in seven 10 patients with T-cell lymphoma" *Blood*, 62:988-995, 1983; and Schroff, R.W., et al. "Human anti-murine immunoglobulin response in patients receiving monoclonal antibody therapy" *Cancer Res.*, 45:879-885, 1985). Even chimeric molecules, where the variable (V) domains of rodent antibodies are fused to human constant (C) regions, are still capable of eliciting a significant immune response (HACA, human anti-chimeric antibody) (Neuberger et al. *Nature (Lond.)*, 314:268-270, 1985). A powerful approach to 15 overcome these limitations in the clinical use of monoclonal antibodies is "humanization" of the murine antibody or antibody from a non-human species (Jones et al. *Nature (Lond.)*, 321:522-525, 1986; Riechman et al., *Nature (Lond.)*, 332:323-327, 1988).

Thus, it is beneficial to produce therapeutic antibodies to the CD20 antigen that create minimal or no antigenicity when administered to patients, especially for chronic treatment. The present invention 20 satisfies this and other needs. The present invention provides anti-CD20 antibodies that overcome the limitations of current therapeutic compositions as well as offer additional advantages that will be apparent from the detailed description below.

#### SUMMARY OF THE INVENTION

25 The present invention provides CD20 binding antibodies or functional fragments thereof, and their use in the treatment of B-cell associated diseases. These antibodies are monoclonal antibodies. In specific embodiments, the antibodies that bind CD20 are humanized or chimeric. The humanized 2H7 variants include those that have amino acid substitutions in the FR and affinity maturation variants with changes in the grafted CDRs. The substituted amino acids in the CDR or FR are not limited to those present in the 30 donor or recipient antibody. In other embodiments, the anti-CD20 antibodies of the invention further comprise changes in amino acid residues in the Fc region that lead to improved effector function including enhanced CDC and/or ADCC function and B-cell killing (also referred to herein as B-cell depletion). Other anti-CD20 antibodies of the invention include those having specific changes that improve stability. In a specific embodiment, the humanized 2H7 variants with increased stability are as described in example 6 35 below. Fucose deficient variants having improved ADCC function in vivo are also provided. In one embodiment, the chimeric anti-CD20 antibody has murine V regions and human C region. One such specific chimeric anti-CD20 antibody is Rituxan® (Rituximab®; Genentech, Inc.).

In a preferred embodiment of all of the antibody compositions and methods of use of this invention, the humanized CD20 binding antibody is 2H7.v16 having the light and heavy chain amino acid sequence of 40 SEQ ID NO. 21 and 22, respectively, as shown in FIG. 6 and FIG. 7. When referring to the polypeptide sequences in Figures 6, 7 and 8, it should be understood that the first 19 or so amino acids that form the secretory signal sequence are not present in the mature polypeptide. The V region of all other variants based on version 16 will have the amino acid sequences of v16 except at the positions of amino acid substitutions

5 which are indicated in the disclosure. Unless otherwise indicated, the 2H7 variants will have the same L chain as that of v16.

The invention provides a humanized antibody that binds human CD20, or an antigen-binding fragment thereof, wherein the antibody is effective to deplete primate B cells in vivo, the antibody comprising in the H chain Variable region ( $V_H$ ) at least a CDR3 sequence of SEQ ID NO. 12 from an anti-human CD20 antibody and substantially the human consensus framework (FR) residues of human heavy chain subgroup III ( $V_{H\text{III}}$ ). In one embodiment, the primate B cells are from human and Cynomolgus monkey. In one embodiment, the antibody further comprises the H chain CDR1 sequence of SEQ ID NO. 10 and CDR2 sequence of SEQ ID NO. 11. In another embodiment, the preceding antibody comprises the L chain CDR1 sequence of SEQ ID NO. 4, CDR2 sequence of SEQ ID NO. 5, CDR3 sequence of SEQ ID NO. 6 with substantially the human consensus framework (FR) residues of human light chain  $\kappa$  subgroup I ( $V_{\kappa\text{I}}$ ). In a preferred embodiment, the FR region in  $V_L$  has a donor antibody residue at position 46; in a specific embodiment, FR2 in  $V_L$  has an amino acid substitution of leuL46pro (Leu in the human  $\kappa$ I consensus sequence changed to pro which is present in the corresponding position in m2H7). The VH region further comprises a donor antibody residue at at least amino acid positions 49, 71 and 73 in the framework. In one embodiment, in the  $V_H$ , the following FR positions in the human heavy chain subgroup III are substituted: AlaH49Gly in FR2; ArgH71Val and AsnH73Lys in FR3. In other embodiments, the CDR regions in the humanized antibody further comprise amino acid substitutions where the residues are neither from donor nor recipient antibody.

25 The antibody of the preceding embodiments can comprise the  $V_H$  sequence of SEQ ID NO.8 of v16, as shown in FIG. 1B. In a further embodiment of the preceding, the antibody further comprises the  $V_L$  sequence of SEQ ID NO.2 of v16, as shown in FIG. 1A.

In other embodiments, the humanized antibody is 2H7.v31 having the light and heavy chain amino acid sequence of SEQ ID NO. 2 and 23, respectively, as shown in FIG. 6 and FIG. 8; 2H7.v31 having the heavy chain amino acid sequence of SEQ ID NO. 23 as shown in FIG. 8; 2H7.v96 with the amino acid 30 substitutions of D56A and N100A in the H chain and S92A in the L chain of v16.

In separate embodiments, the antibody of any of the preceding embodiments further comprises at least one amino acid substitution in the Fc region that improves ADCC and/or CDC activity over the original or parent antibody from which it was derived, v.16 being the parent antibody being compared to in most cases, and Rituxan in other cases. One such antibody with improved activity comprises the triple Alanine 35 substitution of S298A/E333A/K334A in the Fc region. One antibody having S298A/E333A/K334A substitution is 2H7.v31 having the heavy chain amino acid sequence of SEQ ID NO. 23. Antibody 2H7.v114 and 2H7.v115 show at least 10-fold improved ADCC activity as compared to Rituxan.

In another embodiment, the antibody further comprises at least one amino acid substitution in the Fc region that decreases CDC activity as compared to the parent antibody from which it was derived which 40 is v16 in most cases. One such antibody with decreased CDC activity as compared to v16 comprises at least the substitution K322A in the H chain. The comparison of ADCC and CDC activity can be assayed as described in the examples.

5 In a preferred embodiment, the antibodies of the invention are full length antibodies wherein the V<sub>H</sub> region is joined to a human IgG heavy chain constant region. In preferred embodiments, the IgG is human IgG1 or IgG3.

In one embodiment, the CD20 binding antibody is conjugated to a cytotoxic agent. In preferred embodiments the cytotoxic agent is a toxin or a radioactive isotope.

10 In one embodiment, the antibodies of the invention for use in therapeutic or diagnostic purposes are produced in CHO cells.

Also provided is a composition comprising an antibody of any one of the preceding embodiments, and a carrier. In one embodiment, the carrier is a pharmaceutically acceptable carrier. These compositions can be provided in an article of manufacture or a kit.

15 The invention also provided a liquid formulation comprising a humanized 2H7 antibody at 20mg/mL antibody, 10mM histidine sulfate pH5.8, 60mg/ml sucrose (6%), 0.2 mg/ml polysorbate 20 (0.02%).

The invention also provides an isolated nucleic acid that encodes any of the antibodies disclosed herein, including an expression vector for expressing the antibody.

20 Another aspect of the invention are host cells comprising the preceding nucleic acids, and host cells that produce the antibody. In a preferred embodiment of the latter, the host cell is a CHO cell. A method of producing these antibodies is provided, the method comprising culturing the host cell that produces the antibody and recovering the antibody from the cell culture.

25 Yet another aspect of the invention is an article of manufacture comprising a container and a composition contained therein, wherein the composition comprises an antibody of any of the preceding embodiments. For use in treating NHL, the article of manufacture further comprises a package insert indicating that the composition is used to treat non-Hodgkin's lymphoma.

A further aspect of the invention is a method of inducing apoptosis in B cells in vivo, comprising contacting B cells with the antibody of any of the preceding, thereby killing the B cells.

30 The invention also provides methods of treating the diseases disclosed herein by administration of a CD20 binding antibody or functional fragment thereof, to a mammal such as a human patient suffering from the disease. In any of the methods for treating an autoimmune disease or a CD20 positive cancer, in one embodiment, the antibody is 2H7.v16 having the light and heavy chain amino acid sequence of SEQ ID NO. 21 and 22, respectively, as shown in FIG. 6 and FIG. 7. Thus, one embodiment is a method of treating a 35 CD20 positive cancer, comprising administering to a patient suffering from the cancer, a therapeutically effective amount of a humanized CD20 binding antibody of the invention. In preferred embodiments, the CD20 positive cancer is a B cell lymphoma or leukemia including non-Hodgkin's lymphoma (NHL) or lymphocyte predominant Hodgkin's disease (LPHD), chronic lymphocytic leukemia (CLL) or SLL. In one embodiment of the method of treating a B cell lymphoma or leukemia, the antibody is administered at a 40 dosage range of about 275-375mg/m<sup>2</sup>. In additional embodiments, the treatment method further comprises administering to the patient at least one chemotherapeutic agent, wherein for non-Hodgkin's lymphoma (NHL), the chemotherapeutic agent is selected from the group consisting of doxorubicin, cyclophosphamide, vincristine and prednisolone.

5       Also provided is a method of treating an autoimmune disease, comprising administering to a patient suffering from the autoimmune disease, a therapeutically effective amount of the humanized CD20 binding antibody of any one of the preceding claims. The autoimmune disease is selected from the group consisting of rheumatoid arthritis, juvenile rheumatoid arthritis, systemic lupus erythematosus (SLE), Wegener's disease, inflammatory bowel disease, idiopathic thrombocytopenic purpura (ITP), thrombotic  
10      thrombocytopenic purpura (TTP), autoimmune thrombocytopenia, multiple sclerosis, psoriasis, IgA nephropathy, IgM polyneuropathies, myasthenia gravis, vasculitis, diabetes mellitus, Reynaud's syndrome, Sjorgen's syndrome and glomerulonephritis. Where the autoimmune disease is rheumatoid arthritis, the antibody can be administered in conjunction with a second therapeutic agent which is preferably methotrexate.

15       In these treatment methods, the CD20 binding antibodies can be administered alone or in conjunction with a second therapeutic agent such as a second antibody, or a chemotherapeutic agent or an immunosuppressive agent. The second antibody can be one that binds CD20 or a different B cell antigen, or a NK or T cell antigen. In one embodiment, the second antibody is a radiolabeled anti-CD20 antibody. In other embodiments, the CD20 binding antibody is conjugated to a cytotoxic agent including a toxin or a  
20      radioactive isotope.

25       In another aspect, the invention provides a method of treating an autoimmune disease selected from the group consisting of Dermatomyositis, Wegner's granulomatosis, ANCA, Aplastic anemia, Autoimmune hemolytic anemia (AIHA), factor VIII deficiency, hemophilia A, Autoimmune neutropenia, Castleman's syndrome, Goodpasture's syndrome, solid organ transplant rejection, graft versus host disease (GVHD), IgM mediated, thrombotic thrombocytopenic purpura (TTP), Hashimoto's Thyroiditis, autoimmune hepatitis, lymphoid interstitial pneumonitis (HIV), bronchiolitis obliterans (non-transplant) vs. NSIP, Guillain-Barre Syndrome, large vessel vasculitis, giant cell (Takayasu's) arteritis, medium vessel vasculitis, Kawasaki's Disease, polyarteritis nodosa, comprising administering to a patient suffering from the disease, a therapeutically effective amount of a CD20 binding antibody. In one embodiment of this method, the CD20  
30      binding antibody is Rituxan®.

35       The invention also provides an isolated nucleic acid comprising the nucleotide sequence of SEQ ID NO.: \_ of the Cynomolgus monkey CD20 (shown in FIG. 19), or a degenerate variant of this sequence . One embodiment is an isolated nucleic acid comprising a sequence that encodes a polypeptide with the amino acid sequence of SEQ ID NO. \_ (shown FIG. 20), or SEQ ID NO. \_ (FIG. 20) with conservative amino acid substitutions. Another embodiment is a vector comprising the preceding nucleic acid, including an expression vector for expression in a host cell. Included as well is a host cell comprising the vector. Also provided is an isolated polypeptide comprising the amino acid sequence [SEQ ID NO. \_ ; FIG. 20] of the Cynomolgus monkey CD20.

40       **BRIEF DESCRIPTION OF THE FIGURES**

FIG. 1A is a sequence alignment comparing the amino acid sequences of the light chain variable domain ( $V_L$ ) of each of murine 2H7 (SEQ ID NO. 1), humanized 2H7.v16 variant (SEQ ID NO. 2 ), and human kappa light chain subgroup I (SEQ ID NO. 3). The CDRs of  $V_L$  of 2H7 and hu2H7.v16 are as follows: CDR1 (SEQ ID NO.4), CDR2 (SEQ ID NO.5 ), and CDR3 (SEQ ID NO.6).

5 FIG. 1B is a sequence alignment which compares the V<sub>H</sub> sequences of murine 2H7 (SEQ ID NO. 7), humanized 2H7.v16 variant (SEQ ID NO. 8), and the human consensus sequence of heavy chain subgroup III (SEQ ID NO. 9). The CDRs of V<sub>H</sub> of 2H7 and hu2H7.v16 are as follow: CDR1 (SEQ ID NO.10), CDR2 (SEQ ID NO.11), and CDR3 (SEQ ID NO.12).

10 In FIG. 1A and FIG. 1B, the CDR1, CDR2 and CDR3 in each chain are enclosed within brackets, flanked by the framework regions, FR1-FR4, as indicated. 2H7 refers to the murine 2H7 antibody. The asterisks in between two rows of sequences indicate the positions that are different between the two sequences. Residue numbering is according to Kabat et al., Sequences of Immunological Interest. 5th Ed. Public Health Service, National Institutes of Health, Bethesda, Md. (1991), with insertions shown as a, b, c, d, and e.

15 FIG. 2 shows the sequence of phagemid pVX4 (SEQ ID NO.13) used for construction of 2H7 Fab plasmids (see Example 1) as well as the amino acid sequences of the L chain (SEQ ID NO.14) and H chain (SEQ ID NO.15) of the Fab for the CDR-grafted anti-IFN- $\alpha$  humanized antibody.

20 FIG. 3 shows the sequence of the expression plasmid which encodes the chimeric 2H7.v6.8 Fab (SEQ ID NO.16). The amino acid sequences of the L chain (SEQ ID NO.17) and H chain (SEQ ID NO.18) are shown.

FIG. 4 shows the sequence of the plasmid pDR1 (SEQ ID NO.19; 5391 bp) for expression of immunoglobulin light chains as described in Example 1. pDR1 contains sequences encoding an irrelevant antibody, the light chain of a humanized anti-CD3 antibody (Shalaby et al., J. Exp. Med. 175: 217-225 (1992)), the start and stop codons for which are indicated in bold and underlined.

25 FIG. 5 shows the sequence of plasmid pDR2 (SEQ ID NO.20; 6135 bp) for expression of immunoglobulin heavy chains as described in Example 1. pDR2 contains sequences encoding an irrelevant antibody, the heavy chain of a humanized anti-CD3 antibody (Shalaby et al., *supra*), the start and stop codons for which are indicated in bold and underlined.

30 FIG. 6 shows the amino acid sequence of the 2H7.v16 complete L chain (SEQ ID NO.21). The first 19 amino acids before DIQ are the secretory signal sequence not present in the mature polypeptide chain.

FIG. 7 shows the amino acid sequence of the 2H7.v16 complete H chain (SEQ ID NO.22). The first 19 amino acids before EVQ before are the secretory signal sequence not present in the mature polypeptide chain. Aligning the V<sub>H</sub> sequence in FIG. 1B (SEQ ID NO. 8) with the complete H chain sequence, the human  $\gamma$ 1 constant region is from amino acid position 114-471 in SEQ ID NO. 22.

35 FIG. 8 shows the amino acid sequence of the 2H7.v31 complete H chain (SEQ ID NO.23). The first 19 amino acids before EVQ before are the secretory signal sequence not present in the mature polypeptide chain. The L chain is the same as for 2H7.v16 (see FIG. 6).

FIG. 9 shows the relative stability of 2H7.v16 and 2H7.v73 IgG variants. Assay results were normalized to the values prior to incubation and reported as percent remaining after incubation.

40 FIG. 10 is a flow chart summarizing the amino acid changes from the murine 2H7 to a subset of humanized versions up to v75.

FIG. 11 is a summary of mean absolute B-cell count [CD3-/CD40+] in all groups (2H7 study and Rituxan study combined), as described in Example 10.

5 FIG. 12 shows the results of a representative ADCC assay on fucose deficient 2H7 variants as described in Example 11.

FIG. 13 shows the results of the Annexin V staining plotted as a function of antibody concentration. Ramos cells were treated with an irrelevant IgG1 control antibody (Herceptin®; circles), Rituximab (squares), or rhuMAb 2H7.v16 (triangles) in the presence of a crosslinking secondary antibody and were 10 analyzed by FACS. Figures 13-15 are described in Example 13.

FIG. 14 shows the results of the Annexin V and propidium iodide double-staining are plotted as a function of antibody concentration. Ramos cells were treated with an irrelevant IgG1 control antibody (Herceptin®; circles), Rituximab (squares), or rhuMAb 2H7.v16 (triangles) in the presence of a crosslinking secondary antibody and were analyzed by FACS.

15 FIG. 15 shows the counts (per 10 s) of live, unstained cells are plotted as a function of antibody concentration. Ramos cells were treated with an irrelevant IgG1 control antibody (Herceptin®; circles), Rituximab (squares), or rhuMAb 2H7.v16 (triangles) in the presence of a crosslinking secondary antibody and were analyzed by FACS.

FIGs. 16, 17, 18 show inhibition of Raji cell tumor growth in nude mice, as described in Example 20 14. Animals were treated weekly (as indicated by vertical arrows; n=8 mice per group) for 6 weeks with PBS (control) or with Rituxan® or rhuMAb 2H7.v16 at 5 mg/kg (FIG. 16), 0.5 mg/kg (FIG. 17), or 0.05 mg/kg (FIG. 18).

FIG. 19 shows the nucleotide (SEQ ID NO. \_\_) and amino acid (SEQ ID NO. \_\_) sequences of Cynomolgus monkey CD20, as described in Example 15.

25 FIG. 20 shows the amino acid sequence for cynomolgus monkey CD20. Residues that differ from human CD20 are underlined and the human residues are indicated directly below the monkey residue. The putative extracellular domain of the monkey CD20 is in bold type.

FIG. 21 shows the results of Cynomolgus monkey cells expressing CD20 binding to hu2H7.v16, .v31, and Rituxan, as described in Example 15. The antibodies were assayed for the ability to bind and 30 displace FITC-conjugated murine 2H7 binding to cynomolgus CD20.

FIG. 22 shows dose escalation schema for rheumatoid arthritis phase I/II clinical trial.

FIG. 23 shows the vector for expression of 2H7.v16 in CHO cells.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

35 The "CD20" antigen is a non-glycosylated, transmembrane phosphoprotein with a molecular weight of approximately 35 kD that is found on the surface of greater than 90% of B cells from peripheral blood or lymphoid organs. CD20 is expressed during early pre-B cell development and remains until plasma cell differentiation; it is not found on human stem cells, lymphoid progenitor cells or normal plasma cells. CD20 is present on both normal B cells as well as malignant B cells. Other names for CD20 in the literature 40 include "B-lymphocyte-restricted differentiation antigen" and "Bp35". The CD20 antigen is described in, for example, Clark and Ledbetter, *Adv. Can. Res.* 52:81-149 (1989) and Valentine *et al. J. Biol. Chem.* 264(19):11282-11287 (1989).

5        The term "antibody" is used in the broadest sense and specifically covers monoclonal antibodies (including full length monoclonal antibodies), multispecific antibodies (*e.g.*, bispecific antibodies), and antibody fragments so long as they exhibit the desired biological activity or function.

10      The biological activity of the CD20 binding and humanized CD20 binding antibodies of the invention will include at least binding of the antibody to human CD20, more preferably binding to human and other primate CD20 (including cynomolgus monkey, rhesus monkey, chimpanzees). The antibodies would bind CD20 with a  $K_d$  value of no higher than  $1 \times 10^{-8}$ , preferably a  $K_d$  value no higher than about  $1 \times 10^{-9}$ , and be able to kill or deplete B cells *in vivo*, preferably by at least 20% when compared to the appropriate negative control which is not treated with such an antibody. B cell depletion can be a result of one or more of ADCC, CDC, apoptosis, or other mechanism. In some embodiments of disease treatment 15 herein, specific effector functions or mechanisms may be desired over others and certain variants of the humanized 2H7 are preferred to achieve those biological functions, such as ADCC.

20      "Antibody fragments" comprise a portion of a full length antibody, generally the antigen binding or variable region thereof. Examples of antibody fragments include Fab, Fab', F(ab')<sub>2</sub>, and Fv fragments; diabodies; linear antibodies; single-chain antibody molecules; and multispecific antibodies formed from antibody fragments.

25      "Fv" is the minimum antibody fragment which contains a complete antigen-recognition and - binding site. This fragment consists of a dimer of one heavy- and one light-chain variable region domain in tight, non-covalent association. From the folding of these two domains emanate six hypervariable loops (3 loops each from the H and L chain) that contribute the amino acid residues for antigen binding and confer antigen binding specificity to the antibody. However, even a single variable domain (or half of an Fv comprising only three CDRs specific for an antigen) has the ability to recognize and bind antigen, although at a lower affinity than the entire binding site.

30      The term "monoclonal antibody" as used herein refers to an antibody obtained from a population of substantially homogeneous antibodies, *i.e.*, the individual antibodies comprising the population are identical except for possible naturally occurring mutations that may be present in minor amounts. Monoclonal antibodies are highly specific, being directed against a single antigenic site. Furthermore, in contrast to conventional (polyclonal) antibody preparations which typically include different antibodies directed against different determinants (epitopes), each monoclonal antibody is directed against a single determinant on the antigen. The modifier "monoclonal" indicates the character of the antibody as being obtained from a 35 substantially homogeneous population of antibodies, and is not to be construed as requiring production of the antibody by any particular method. For example, the monoclonal antibodies to be used in accordance with the present invention may be made by the hybridoma method first described by Kohler *et al.*, *Nature* 256:495 (1975), or may be made by recombinant DNA methods (see, *e.g.*, U.S. Patent No. 4,816,567). The "monoclonal antibodies" may also be isolated from phage antibody libraries using the techniques described 40 in Clackson *et al.*, *Nature* 352:624-628 (1991) and Marks *et al.*, *J. Mol. Biol.* 222:581-597 (1991), for example.

      "Functional fragments" of the CD20 binding antibodies of the invention are those fragments that retain binding to CD20 with substantially the same affinity as the intact full length molecule from which

5 they are derived and show biological activity including depleting B cells as measured by in vitro or in vivo assays such as those described herein.

The term "variable" refers to the fact that certain segments of the variable domains differ extensively in sequence among antibodies. The V domain mediates antigen binding and define specificity of a particular antibody for its particular antigen. However, the variability is not evenly distributed across the 10 110-amino acid span of the variable domains. Instead, the V regions consist of relatively invariant stretches called framework regions (FRs) of 15-30 amino acids separated by shorter regions of extreme variability called "hypervariable regions" that are each 9-12 amino acids long. The variable domains of native heavy and light chains each comprise four FRs, largely adopting a  $\beta$ -sheet configuration, connected by three hypervariable regions, which form loops connecting, and in some cases forming part of, the  $\beta$ -sheet 15 structure. The hypervariable regions in each chain are held together in close proximity by the FRs and, with the hypervariable regions from the other chain, contribute to the formation of the antigen-binding site of antibodies (see Kabat et al., Sequences of Proteins of Immunological Interest, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD. (1991)). The constant domains are not involved directly in 20 binding an antibody to an antigen, but exhibit various effector functions, such as participation of the antibody in antibody dependent cellular cytotoxicity (ADCC).

The term "hypervariable region" when used herein refers to the amino acid residues of an antibody which are responsible for antigen-binding. The hypervariable region generally comprises amino acid residues from a "complementarity determining region" or "CDR" (e.g. around about residues 24-34 (L1), 25 50-56 (L2) and 89-97 (L3) in the V<sub>L</sub>, and around about 31-35B (H1), 50-65 (H2) and 95-102 (H3) in the V<sub>H</sub> (Kabat et al., Sequences of Proteins of Immunological Interest, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD. (1991)) and/or those residues from a "hypervariable loop" (e.g. residues 26-32 (L1), 50-52 (L2) and 91-96 (L3) in the V<sub>L</sub>, and 26-32 (H1), 52A-55 (H2) and 96-101 (H3) in the V<sub>H</sub> (Chothia and Lesk *J. Mol. Biol.* 196:901-917 (1987)).

As referred to herein, the "consensus sequence" or consensus V domain sequence is an artificial 30 sequence derived from a comparison of the amino acid sequences of known human immunoglobulin variable region sequences. Based on these comparisons, recombinant nucleic acid sequences encoding the V domain amino acids that are a consensus of the sequences derived from the human  $\kappa$  and the human H chain subgroup III V domains were prepared. The consensus V sequence does not have any known antibody binding specificity or affinity.

"Chimeric" antibodies (immunoglobulins) have a portion of the heavy and/or light chain identical 35 with or homologous to corresponding sequences in antibodies derived from a particular species or belonging to a particular antibody class or subclass, while the remainder of the chain(s) is identical with or homologous to corresponding sequences in antibodies derived from another species or belonging to another antibody class or subclass, as well as fragments of such antibodies, so long as they exhibit the desired biological 40 activity (U.S. Patent No. 4,816,567; and Morrison et al., *Proc. Natl. Acad. Sci. USA* 81:6851-6855 (1984)). Humanized antibody as used herein is a subset of chimeric antibodies.

"Humanized" forms of non-human (e.g., murine) antibodies are chimeric antibodies which contain minimal sequence derived from non-human immunoglobulin. For the most part, humanized antibodies are

5 human immunoglobulins (recipient or acceptor antibody) in which hypervariable region residues of the recipient are replaced by hypervariable region residues from a non-human species (donor antibody) such as mouse, rat, rabbit or nonhuman primate having the desired specificity, affinity, and capacity. In some instances, Fv framework region (FR) residues of the human immunoglobulin are replaced by corresponding non-human residues. Furthermore, humanized antibodies may comprise residues which are not found in the  
10 recipient antibody or in the donor antibody. These modifications are made to further refine antibody performance such as binding affinity. Generally, the humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the hypervariable loops correspond to those of a non-human immunoglobulin and all or substantially all of the FR regions are those of a human immunoglobulin sequence although the FR regions may include one or more amino acid  
15 substitutions that improve binding affinity. The number of these amino acid substitutions in the FR are typically no more than 6 in the H chain, and in the L chain, no more than 3. The humanized antibody optionally also will comprise at least a portion of an immunoglobulin constant region (Fc), typically that of a human immunoglobulin. For further details, see Jones *et al.*, *Nature* 321:522-525 (1986); Reichmann *et al.*, *Nature* 332:323-329 (1988); and Presta, *Curr. Op. Struct. Biol.* 2:593-596 (1992).

20 Antibody "effector functions" refer to those biological activities attributable to the Fc region (a native sequence Fc region or amino acid sequence variant Fc region) of an antibody, and vary with the antibody isotype. Examples of antibody effector functions include: C1q binding and complement dependent cytotoxicity; Fc receptor binding; antibody-dependent cell-mediated cytotoxicity (ADCC); phagocytosis; down regulation of cell surface receptors (e.g. B cell receptor); and B cell activation.

25 "Antibody-dependent cell-mediated cytotoxicity" or "ADCC" refers to a form of cytotoxicity in which secreted Ig bound onto Fc receptors (FcRs) present on certain cytotoxic cells (e.g. Natural Killer (NK) cells, neutrophils, and macrophages) enable these cytotoxic effector cells to bind specifically to an antigen-bearing target cell and subsequently kill the target cell with cytotoxins. The antibodies "arm" the cytotoxic cells and are absolutely required for such killing. The primary cells for mediating ADCC, NK cells, express  
30 Fc $\gamma$ RIII only, whereas monocytes express Fc $\gamma$ RI, Fc $\gamma$ RII and Fc $\gamma$ RIII. FcR expression on hematopoietic cells is summarized in Table 3 on page 464 of Ravetch and Kinet, *Annu. Rev. Immunol.* 9:457-92 (1991). To assess ADCC activity of a molecule of interest, an *in vitro* ADCC assay, such as that described in US Patent No. 5,500,362 or 5,821,337 may be performed. Useful effector cells for such assays include peripheral blood mononuclear cells (PBMC) and Natural Killer (NK) cells. Alternatively, or additionally, ADCC  
35 activity of the molecule of interest may be assessed *in vivo*, e.g., in a animal model such as that disclosed in Clynes *et al.* *PNAS (USA)* 95:652-656 (1998).

40 "Fc receptor" or "FcR" describes a receptor that binds to the Fc region of an antibody. The preferred FcR is a native sequence human FcR. Moreover, a preferred FcR is one which binds an IgG antibody (a gamma receptor) and includes receptors of the Fc $\gamma$ RI, Fc $\gamma$ RII, and Fc $\gamma$ RIII subclasses, including allelic variants and alternatively spliced forms of these receptors. Fc $\gamma$ RII receptors include Fc $\gamma$ RIIA (an "activating receptor") and Fc $\gamma$ RIIB (an "inhibiting receptor"), which have similar amino acid sequences that differ primarily in the cytoplasmic domains thereof. Activating receptor Fc $\gamma$ RIIA contains an immunoreceptor tyrosine-based activation motif (ITAM) in its cytoplasmic domain. Inhibiting receptor Fc $\gamma$ RIIB contains an immunoreceptor tyrosine-based inhibition motif (ITIM) in its cytoplasmic domain. (see

5 review M. in Daëron, *Annu. Rev. Immunol.* 15:203-234 (1997)). FcRs are reviewed in Ravetch and Kinet, *Annu. Rev. Immunol.* 9:457-92 (1991); Capel *et al.*, *Immunomethods* 4:25-34 (1994); and de Haas *et al.*, *J. Lab. Clin. Med.* 126:330-41 (1995). Other FcRs, including those to be identified in the future, are encompassed by the term "FcR" herein. The term also includes the neonatal receptor, FcRn, which is responsible for the transfer of maternal IgGs to the fetus (Guyer *et al.*, *J. Immunol.* 117:587 (1976) and Kim *et al.*, *J. Immunol.* 24:249 (1994)).

10 WO00/42072 (Presta) describes antibody variants with improved or diminished binding to FcRs. The content of that patent publication is specifically incorporated herein by reference. See, also, Shields *et al.* *J. Biol. Chem.* 9(2): 6591-6604 (2001).

15 "Human effector cells" are leukocytes which express one or more FcRs and perform effector functions. Preferably, the cells express at least Fc $\gamma$ RIII and perform ADCC effector function. Examples of human leukocytes which mediate ADCC include peripheral blood mononuclear cells (PBMC), natural killer (NK) cells, monocytes, cytotoxic T cells and neutrophils; with PBMCs and NK cells being preferred. The effector cells may be isolated from a native source, e.g. from blood.

20 "Complement dependent cytotoxicity" or "CDC" refers to the lysis of a target cell in the presence of complement. Activation of the classical complement pathway is initiated by the binding of the first component of the complement system (C1q) to antibodies (of the appropriate subclass) which are bound to their cognate antigen. To assess complement activation, a CDC assay, e.g. as described in Gazzano-Santoro *et al.*, *J. Immunol. Methods* 202:163 (1996), may be performed.

25 Polypeptide variants with altered Fc region amino acid sequences and increased or decreased C1q binding capability are described in US patent No. 6,194,551B1 and WO99/51642. The contents of those patent publications are specifically incorporated herein by reference. See, also, Idusogie *et al.* *J. Immunol.* 164: 4178-4184 (2000).

30 The N-glycosylation site in IgG is at Asn297 in the CH2 domain. The present invention also provides compositions of a CD20-binding, humanized antibody having a Fc region, wherein about 80-100% (and preferably about 90-99%) of the antibody in the composition comprises a mature core carbohydrate structure which lacks fucose, attached to the Fc region of the glycoprotein. Such compositions were demonstrated herein to exhibit a surprising improvement in binding to Fc $\gamma$ RIIIA(F158), which is not as effective as Fc $\gamma$ RIIIA (V158) in interacting with human IgG. Thus, the compositions herein are anticipated to be superior to previously described anti-CD20 antibody compositions, especially for therapy of human 35 patients who express Fc $\gamma$ RIIIA (F158). Fc $\gamma$ RIIIA (F158) is more common than Fc $\gamma$ RIIIA (V158) in normal, healthy African Americans and Caucasians. See Lehrnbecher *et al.* *Blood* 94:4220 (1999). The present application further demonstrates the synergistic increase in Fc $\gamma$ RIII binding and/or ADCC function that results from combining the glycosylation variations herein with amino acid sequence modification(s) in the Fc region of the glycoprotein.

40 An "isolated" antibody is one which has been identified and separated and/or recovered from a component of its natural environment. Contaminant components of its natural environment are materials which would interfere with diagnostic or therapeutic uses for the antibody, and may include enzymes, hormones, and other proteinaceous or nonproteinaceous solutes. In preferred embodiments, the antibody will be purified (1) to greater than 95% by weight of antibody as determined by the Lowry method, and most

5 preferably more than 99% by weight, (2) to a degree sufficient to obtain at least 15 residues of N-terminal or internal amino acid sequence by use of a spinning cup sequenator, or (3) to homogeneity by SDS-PAGE under reducing or nonreducing conditions using Coomassie blue or, preferably, silver stain. Isolated antibody includes the antibody *in situ* within recombinant cells since at least one component of the antibody's natural environment will not be present. Ordinarily, however, isolated antibody will be prepared  
10 by at least one purification step.

An "isolated" nucleic acid molecule is a nucleic acid molecule that is identified and separated from at least one contaminant nucleic acid molecule with which it is ordinarily associated in the natural source of the antibody nucleic acid. An isolated nucleic acid molecule is other than in the form or setting in which it is found in nature. Isolated nucleic acid molecules therefore are distinguished from the nucleic acid molecule  
15 as it exists in natural cells. However, an isolated nucleic acid molecule includes a nucleic acid molecule contained in cells that ordinarily express the antibody where, for example, the nucleic acid molecule is in a chromosomal location different from that of natural cells.

The expression "control sequences" refers to DNA sequences necessary for the expression of an operably linked coding sequence in a particular host organism. The control sequences that are suitable for  
20 prokaryotes, for example, include a promoter, optionally an operator sequence, and a ribosome binding site. Eukaryotic cells are known to utilize promoters, polyadenylation signals, and enhancers.

Nucleic acid is "operably linked" when it is placed into a functional relationship with another nucleic acid sequence. For example, DNA for a presequence or secretory leader is operably linked to DNA for a polypeptide if it is expressed as a preprotein that participates in the secretion of the polypeptide; a  
25 promoter or enhancer is operably linked to a coding sequence if it affects the transcription of the sequence; or a ribosome binding site is operably linked to a coding sequence if it is positioned so as to facilitate translation. Generally, "operably linked" means that the DNA sequences being linked are contiguous, and, in the case of a secretory leader, contiguous and in reading phase. However, enhancers do not have to be contiguous. Linking is accomplished by ligation at convenient restriction sites. If such sites do not exist, the  
30 synthetic oligonucleotide adaptors or linkers are used in accordance with conventional practice.

"Vector" includes shuttle and expression vectors. Typically, the plasmid construct will also include an origin of replication (*e.g.*, the ColE1 origin of replication) and a selectable marker (*e.g.*, ampicillin or tetracycline resistance), for replication and selection, respectively, of the plasmids in bacteria. An "expression vector" refers to a vector that contains the necessary control sequences or regulatory elements  
35 for expression of the antibodies including antibody fragment of the invention, in bacterial or eukaryotic cells. Suitable vectors are disclosed below.

The cell that produces a humanized CD20 binding antibody of the invention will include the bacterial and eukaryotic host cells into which nucleic acid encoding the antibodies have been introduced. Suitable host cells are disclosed below.

40 The word "label" when used herein refers to a detectable compound or composition which is conjugated directly or indirectly to the antibody. The label may itself be detectable by itself (*e.g.*, radioisotope labels or fluorescent labels) or, in the case of an enzymatic label, may catalyze chemical alteration of a substrate compound or composition which is detectable.

5 An "autoimmune disease" herein is a non-malignant disease or disorder arising from and directed against an individual's own (self) antigens and/or tissues.

As used herein, "B cell depletion" refers to a reduction in B cell levels in an animal or human after drug or antibody treatment, as compared to the B cell level before treatment. B cell levels are measurable using well known assays such as those described in the Experimental Examples. B cell depletion can be complete or partial. In one embodiment, the depletion of CD20 expressing B cells is at least 25%. Not to be limited by any one mechanism, possible mechanisms of B-cell depletion include ADCC, CDC, apoptosis, modulation of calcium flux or a combination of two or more of the preceding.

The term "cytotoxic agent" as used herein refers to a substance that inhibits or prevents the function of cells and/or causes destruction of cells. The term is intended to include radioactive isotopes (e.g., I<sup>131</sup>, 15 I<sup>125</sup>, Y<sup>90</sup> and Re<sup>186</sup>), chemotherapeutic agents, and toxins such as enzymatically active toxins of bacterial, fungal, plant or animal origin, or fragments thereof.

A "chemotherapeutic agent" is a chemical compound useful in the treatment of cancer. Examples of chemotherapeutic agents include alkalyzing or alkylating agents such as thiotepla and cyclophosphamide (CYTOXANTM); alkyl sulfonates such as busulfan, improsulfan and piposulfan; aziridines such as 20 benzodopa, carboquone, meturedopa, and uredopa; ethylenimines and methylamelamines including altretamine, triethylenemelamine, triethylenephosphoramide, triethylenethiophosphoramide and trimethylolomelamine; nitrogen mustards such as chlorambucil, chlornaphazine, chlophosphamide, estramustine, ifosfamide, mechlorethamine, mechlorethamine oxide hydrochloride, melphalan, novembichin, phenesterine, prednimustine, trofosfamide, uracil mustard; nitrosureas such as carmustine, chlorozotocin, 25 fotemustine, lomustine, nimustine, ranimustine; antibiotics such as aclacinomysins, actinomycin, authramycin, azaserine, bleomycins, cactinomycin, calicheamicin, carabacin, carminomycin, carzinophilin, chromomycins, dactinomycin, daunorubicin, detorubicin, 6-diazo-5-oxo-L-norleucine, doxorubicin (Adriamycin), epirubicin, esorubicin, idarubicin, marcellomycin, mitomycins, mycophenolic acid, nogalamycin, olivomycins, peplomycin, potfiromycin, puromycin, quelamycin, rodorubicin, streptonigrin, 30 streptozocin, tubercidin, ubenimex, zinostatin, zorubicin; anti-metabolites such as methotrexate and 5-fluorouracil (5-FU); folic acid analogues such as denopterin, methotrexate, pteropterin, trimetrexate; purine 35 analogs such as fludarabine, 6-mercaptopurine, thiamiprime, thioguanine; pyrimidine analogs such as ancitabine, azacitidine, 6-azauridine, carmofur, cytarabine, dideoxyuridine, doxifluridine, enocitabine, floxuridine, 5-FU; androgens such as calusterone, dromostanolone propionate, epitostanol, mepitiostane, 40 testolactone; anti-adrenals such as aminoglutethimide, mitotane, trilostane; folic acid replenisher such as frolic acid; aceglatone; aldophosphamide glycoside; aminolevulinic acid; amsacrine; bestrobucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone; el fornithine; elliptinium acetate; etoglucid; gallium nitrate; hydroxyurea; lentinan; lonidamine; mitoguazone; mitoxantrone; mopidamol; nitracrine; pentostatin; phenamet; pirarubicin; podophyllinic acid; 2-ethylhydrazide; procarbazine; PSK®; razoxane; sизofiran; spirogermanium; tenuazonic acid; triaziquone; 2, 2'-trichloroethylamine; urethan; vindesine; dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; arabinoside ("Ara-C"); thiotepla; taxoids, e.g. paclitaxel (TAXOL®, Bristol-Myers Squibb Oncology, Princeton, NJ) and doxetaxel (TAXOTERE®, Rhône-Poulenc Rorer, Antony, France); chlorambucil; gemcitabine; 6-thioguanine; mercaptoperpurine; methotrexate; platinum analogs such as cisplatin and carboplatin; platinum; etoposide (VP-

5        16); ifosfamide; mitomycin C; mitoxantrone; vincristine; vinblastine; vinorelbine; navelbine; novantrone; teniposide; daunomycin; aminopterin; xeloda; ibandronate; CPT-11; topoisomerase inhibitor RFS 2000; difluoromethylornithine (DMFO); retinoic acid; esperamicins; capecitabine; and pharmaceutically acceptable salts, acids or derivatives of any of the above. Also included in this definition are anti-hormonal agents that act to regulate or inhibit hormone action on tumors such as anti-estrogens including for example  
10 tamoxifen, raloxifene, aromatase inhibiting 4(5)-imidazoles, 4-hydroxytamoxifen, trioxifene, keoxifene, LY117018, onapristone, and toremifene (Fareston); anti-androgens such as flutamide, nilutamide, bicalutamide, leuprolide, and goserelin; other chemotherapeutic agents such as prednisolone. Pharmaceutically acceptable salts, acids or derivatives of any of the above are included.

"Treating" or "treatment" or "alleviation" refers to both therapeutic treatment and prophylactic or preventative measures, wherein the object is to prevent or slow down (lessen) the targeted pathologic condition or disorder. A subject is successfully "treated" for a CD20 positive cancer or an autoimmune disease if, after receiving a therapeutic amount of a CD20 binding antibody of the invention according to the methods of the present invention, the subject shows observable and/or measurable reduction in or absence of one or more signs and symptoms of the particular disease. For example, for cancer, reduction in the number  
20 of cancer cells or absence of the cancer cells; reduction in the tumor size; inhibition (*i.e.*, slow to some extent and preferably stop) of tumor metastasis; inhibition, to some extent, of tumor growth; increase in length of remission, and/or relief to some extent, one or more of the symptoms associated with the specific cancer; reduced morbidity and mortality, and improvement in quality of life issues. Reduction of the signs or symptoms of a disease may also be felt by the patient. Treatment can achieve a complete response,  
25 defined as disappearance of all signs of cancer, or a partial response, wherein the size of the tumor is decreased, preferably by more than 50 percent, more preferably by 75%. A patient is also considered treated if the patient experiences stable disease. In a preferred embodiment, the cancer patients are still progression-free in the cancer after one year, preferably after 15 months. These parameters for assessing successful treatment and improvement in the disease are readily measurable by routine procedures familiar  
30 to a physician of appropriate skill in the art.

A "therapeutically effective amount" refers to an amount of an antibody or a drug effective to "treat" a disease or disorder in a subject. In the case of cancer, the therapeutically effective amount of the drug may reduce the number of cancer cells; reduce the tumor size; inhibit (*i.e.*, slow to some extent and preferably stop) cancer cell infiltration into peripheral organs; inhibit (*i.e.*, slow to some extent and  
35 preferably stop) tumor metastasis; inhibit, to some extent, tumor growth; and/or relieve to some extent one or more of the symptoms associated with the cancer. See preceding definition of "treating".

"Chronic" administration refers to administration of the agent(s) in a continuous mode as opposed to an acute mode, so as to maintain the initial therapeutic effect (activity) for an extended period of time. "Intermittent" administration is treatment that is not consecutively done without interruption, but rather is  
40 cyclic in nature.

### Compositions and Methods of the Invention

The invention provides humanized antibodies that bind human CD20, and preferably other primate CD20 as well, comprising a H chain having at least one, preferably two or all of the H chain CDRs of a non-

5 human species anti-human CD20 antibody (donor antibody), and substantially all of the framework residues  
of a human consensus antibody as the recipient antibody. The donor antibody can be from various non-  
human species including mouse, rat, guinea pig, goat, rabbit, horse, primate but most frequently will be a  
murine antibody. "Substantially all" in this context is meant that the recipient FR regions in the humanized  
antibody may include one or more amino acid substitutions not originally present in the human consensus  
10 FR sequence. These FR changes may comprise residues not found in the recipient or the donor antibody.

In one embodiment, the donor antibody is the murine 2H7 antibody, the V region including the  
CDR and FR sequences of each of the H and L chains of which are shown in FIG. 1A and 1B. In a specific  
embodiment, the residues for the human Fab framework correspond to the consensus sequence of human  
15  $V_k$  subgroup I and of  $V_H$  subgroup III, these consensus sequences are shown in Figure 1A and Figure 1B,  
respectively. The humanized 2H7 antibody of the invention will have at least one of the CDRs in the H  
chain of the murine donor antibody. In one embodiment, the humanized 2H7 antibody that binds human  
CD20 comprises the CDRs of both the H and L chains of the donor antibody.

20 In a full length antibody, the humanized CD20 binding antibody of the invention will comprise a  
humanized V domain joined to a C domain of a human immunoglobulin. In a preferred embodiment, the H  
chain C region is from human IgG, preferably IgG1 or IgG3. The L chain C domain is preferably from  
human  $\kappa$  chain.

25 Unless indicated otherwise, a humanized 2H7 antibody version herein will have the V and C  
domain sequences of 2H7.v16 L chain (FIG. 6, SEQ ID NO. 21) and H chain (FIG 7., SEQ ID NO. 22)  
except at the positions of amino acid substitutions or changes indicated in the experimental examples below.

The humanized CD20 binding antibodies will bind at least human CD20 and preferably bind other  
30 primate CD20 such as that of monkeys including cynomolgus and rhesus monkeys, and chimpanzees. The  
sequence of the cynomolgus monkey CD20 is disclosed in Example 15 and Figure 19

The biological activity of the CD20 binding antibodies and humanized CD20 binding antibodies of  
the invention will include at least binding of the antibody to human CD20, more preferably binding to  
35 human and primate CD20 (including cynomolgus monkey, rhesus monkey, chimpanzees), with a  $K_d$  value of  
no higher than  $1 \times 10^{-8}$ , preferably a  $K_d$  value no higher than about  $1 \times 10^{-9}$ , even more preferably a  $K_d$  value  
no higher than about  $1 \times 10^{-10}$ , and be able to kill or deplete B cells in vitro or in vivo, preferably by at least  
20% when compared to the baseline level or appropriate negative control which is not treated with such an  
antibody.

40 The desired level of B cell depletion will depend on the disease. For the treatment of a CD20  
positive cancer, it may be desirable to maximize the depletion of the B cells which are the target of the anti-  
CD20 antibodies of the invention. Thus, for the treatment of a CD20 positive B cell neoplasm, it is desirable  
that the B cell depletion be sufficient to at least prevent progression of the disease which can be assessed by  
the physician of skill in the art, e.g., by monitoring tumor growth (size), proliferation of the cancerous cell  
type, metastasis, other signs and symptoms of the particular cancer. Preferably, the B cell depletion is  
sufficient to prevent progression of disease for at least 2 months, more preferably 3 months, even more  
preferably 4 months, more preferably 5 months, even more preferably 6 or more months. In even more  
preferred embodiments, the B cell depletion is sufficient to increase the time in remission by at least 6  
months, more preferably 9 months, more preferably one year, more preferably 2 years, more preferably 3

5 years, even more preferably 5 or more years. In a most preferred embodiment, the B cell depletion is sufficient to cure the disease. In preferred embodiments, the B cell depletion in a cancer patient is at least about 75% and more preferably, 80%, 85%, 90%, 95%, 99% and even 100% of the baseline level before treatment.

For treatment of an autoimmune disease, it may be desirable to modulate the extent of B cell depletion depending on the disease and/or the severity of the condition in the individual patient, by adjusting the dosage of CD20 binding antibody. Thus, B cell depletion can but does not have to be complete. Or, total B cell depletion may be desired in initial treatment but in subsequent treatments, the dosage may be adjusted to achieve only partial depletion. In one embodiment, the B cell depletion is at least 20%, i.e., 80% or less of CD20 positive B cells remain as compared to the baseline level before treatment. In other 15 embodiments, B cell depletion is 25%, 30%, 40%, 50%, 60%, 70% or greater. Preferably, the B cell depletion is sufficient to halt progression of the disease, more preferably to alleviate the signs and symptoms of the particular disease under treatment, even more preferably to cure the disease.

The invention also provides bispecific CD20 binding antibodies wherein one arm of the antibody has a humanized H and L chain of the humanized CD20 binding antibody of the invention, and the other arm 20 has V region binding specificity for a second antigen. In specific embodiments, the second antigen is selected from the group consisting of CD3, CD64, CD32A, CD16, NKG2D or other NK activating ligands.

In comparison with Rituxan (rituximab), v16 exhibits about 2 to 5 fold increased ADCC potency, ~3-4 fold decreased CDC than Rituxan.

## 25 Antibody production

### *Monoclonal antibodies*

Monoclonal antibodies may be made using the hybridoma method first described by Kohler *et al.*, *Nature*, 256:495 (1975), or may be made by recombinant DNA methods (U.S. Patent No. 4,816,567).

In the hybridoma method, a mouse or other appropriate host animal, such as a hamster, is 30 immunized as described above to elicit lymphocytes that produce or are capable of producing antibodies that will specifically bind to the protein used for immunization. Alternatively, lymphocytes may be immunized *in vitro*. After immunization, lymphocytes are isolated and then fused with a myeloma cell line using a suitable fusing agent, such as polyethylene glycol, to form a hybridoma cell (Goding, *Monoclonal Antibodies: Principles and Practice*, pp.59-103 (Academic Press, 1986)).

35 The hybridoma cells thus prepared are seeded and grown in a suitable culture medium which medium preferably contains one or more substances that inhibit the growth or survival of the unfused, parental myeloma cells (also referred to as fusion partner). For example, if the parental myeloma cells lack the enzyme hypoxanthine guanine phosphoribosyl transferase (HGPRT or HPRT), the selective culture medium for the hybridomas typically will include hypoxanthine, aminopterin, and thymidine (HAT 40 medium), which substances prevent the growth of HGPRT-deficient cells.

Preferred fusion partner myeloma cells are those that fuse efficiently, support stable high-level production of antibody by the selected antibody-producing cells, and are sensitive to a selective medium that selects against the unfused parental cells. Preferred myeloma cell lines are murine myeloma lines, such as those derived from MOPC-21 and MPC-11 mouse tumors available from the Salk Institute Cell Distribution

5 Center, San Diego, California USA, and SP-2 and derivatives e.g., X63-Ag8-653 cells available from the American Type Culture Collection, Rockville, Maryland USA. Human myeloma and mouse-human heteromyeloma cell lines also have been described for the production of human monoclonal antibodies (Kozbor, *J. Immunol.*, 133:3001 (1984); and Brodeur *et al.*, *Monoclonal Antibody Production Techniques and Applications*, pp. 51-63 (Marcel Dekker, Inc., New York, 1987)).

10 Culture medium in which hybridoma cells are growing is assayed for production of monoclonal antibodies directed against the antigen. Preferably, the binding specificity of monoclonal antibodies produced by hybridoma cells is determined by immunoprecipitation or by an *in vitro* binding assay, such as radioimmunoassay (RIA) or enzyme-linked immunosorbent assay (ELISA).

15 The binding affinity of the monoclonal antibody can, for example, be determined by the Scatchard analysis described in Munson *et al.*, *Anal. Biochem.*, 107:220 (1980).

Once hybridoma cells that produce antibodies of the desired specificity, affinity, and/or activity are identified, the clones may be subcloned by limiting dilution procedures and grown by standard methods (Goding, *Monoclonal Antibodies: Principles and Practice*, pp.59-103 (Academic Press, 1986)). Suitable culture media for this purpose include, for example, D-MEM or RPMI-1640 medium. In addition, the 20 hybridoma cells may be grown *in vivo* as ascites tumors in an animal e.g., by i.p. injection of the cells into mice.

The monoclonal antibodies secreted by the subclones are suitably separated from the culture medium, ascites fluid, or serum by conventional antibody purification procedures such as, for example, affinity chromatography (e.g., using protein A or protein G-Sepharose) or ion-exchange chromatography, 25 hydroxylapatite chromatography, gel electrophoresis, dialysis, etc.

DNA encoding the monoclonal antibodies is readily isolated and sequenced using conventional procedures (e.g., by using oligonucleotide probes that are capable of binding specifically to genes encoding the heavy and light chains of murine antibodies). The hybridoma cells serve as a preferred source of such DNA. Once isolated, the DNA may be placed into expression vectors, which are then transfected into host 30 cells such as *E. coli* cells, simian COS cells, Chinese Hamster Ovary (CHO) cells, or myeloma cells that do not otherwise produce antibody protein, to obtain the synthesis of monoclonal antibodies in the recombinant host cells. Review articles on recombinant expression in bacteria of DNA encoding the antibody include Skerra *et al.*, *Curr. Opinion in Immunol.*, 5:256-262 (1993) and Plückthum, *Immunol. Revs.*, 130:151-188 (1992).

35 In a further embodiment, monoclonal antibodies or antibody fragments can be isolated from antibody phage libraries generated using the techniques described in McCafferty *et al.*, *Nature*, 348:552-554 (1990). Clackson *et al.*, *Nature*, 352:624-628 (1991) and Marks *et al.*, *J. Mol. Biol.*, 222:581-597 (1991) describe the isolation of murine and human antibodies, respectively, using phage libraries. Subsequent publications describe the production of high affinity (nM range) human antibodies by chain shuffling (Marks 40 *et al.*, *Bio/Technology*, 10:779-783 (1992)), as well as combinatorial infection and *in vivo* recombination as a strategy for constructing very large phage libraries (Waterhouse *et al.*, *Nuc. Acids. Res.*, 21:2265-2266 (1993)). Thus, these techniques are viable alternatives to traditional monoclonal antibody hybridoma techniques for isolation of monoclonal antibodies.

5       The DNA that encodes the antibody may be modified to produce chimeric or fusion antibody polypeptides, for example, by substituting human heavy chain and light chain constant domain ( $C_H$  and  $C_L$ ) sequences for the homologous murine sequences (U.S. Patent No. 4,816,567; and Morrison, *et al.*, *Proc. Natl Acad. Sci. USA*, 81:6851 (1984)), or by fusing the immunoglobulin coding sequence with all or part of the coding sequence for a non-immunoglobulin polypeptide (heterologous polypeptide). The non-  
10 immunoglobulin polypeptide sequences can substitute for the constant domains of an antibody, or they are substituted for the variable domains of one antigen-combining site of an antibody to create a chimeric bivalent antibody comprising one antigen-combining site having specificity for an antigen and another antigen-combining site having specificity for a different antigen.

15       *Humanized antibodies*

Methods for humanizing non-human antibodies have been described in the art. Preferably, a humanized antibody has one or more amino acid residues introduced into it from a source which is non-human. These non-human amino acid residues are often referred to as "import" residues, which are typically taken from an "import" variable domain. Humanization can be essentially performed following the method 20 of Winter and co-workers (Jones *et al.*, *Nature*, 321:522-525 (1986); Reichmann *et al.*, *Nature*, 332:323-327 (1988); Verhoeyen *et al.*, *Science*, 239:1534-1536 (1988)), by substituting hypervariable region sequences for the corresponding sequences of a human antibody. Accordingly, such "humanized" antibodies are chimeric antibodies (U.S. Patent No. 4,816,567) wherein substantially less than an intact human variable domain has been substituted by the corresponding sequence from a non-human species. In practice, 25 humanized antibodies are typically human antibodies in which some hypervariable region residues and possibly some FR residues are substituted by residues from analogous sites in rodent antibodies.

The choice of human variable domains, both light and heavy, to be used in making the humanized antibodies is very important to reduce antigenicity and HAMA response (human anti-mouse antibody) when the antibody is intended for human therapeutic use. According to the so-called "best-fit" method, the 30 sequence of the variable domain of a rodent antibody is screened against the entire library of known human variable domain sequences. The human V domain sequence which is closest to that of the rodent is identified and the human framework region (FR) within it accepted for the humanized antibody (Sims *et al.*, *J. Immunol.*, 151:2296 (1993); Chothia *et al.*, *J. Mol. Biol.*, 196:901 (1987)). Another method uses a particular framework region derived from the consensus sequence of all human antibodies of a particular 35 subgroup of light or heavy chains. The same framework may be used for several different humanized antibodies (Carter *et al.*, *Proc. Natl. Acad. Sci. USA*, 89:4285 (1992); Presta *et al.*, *J. Immunol.*, 151:2623 (1993)).

It is further important that antibodies be humanized with retention of high binding affinity for the antigen and other favorable biological properties. To achieve this goal, according to a preferred method, 40 humanized antibodies are prepared by a process of analysis of the parental sequences and various conceptual humanized products using three-dimensional models of the parental and humanized sequences. Three-dimensional immunoglobulin models are commonly available and are familiar to those skilled in the art. Computer programs are available which illustrate and display probable three-dimensional conformational structures of selected candidate immunoglobulin sequences. Inspection of these displays permits analysis of

5 the likely role of the residues in the functioning of the candidate immunoglobulin sequence, *i.e.*, the analysis of residues that influence the ability of the candidate immunoglobulin to bind its antigen. In this way, FR residues can be selected and combined from the recipient and import sequences so that the desired antibody characteristic, such as increased affinity for the target antigen(s), is achieved. In general, the hypervariable region residues are directly and most substantially involved in influencing antigen binding.

10 The humanized antibody may be an antibody fragment, such as a Fab, which is optionally conjugated with one or more cytotoxic agent(s) in order to generate an immunoconjugate. Alternatively, the humanized antibody may be an full length antibody, such as an full length IgG1 antibody.

*Human antibodies and phage display methodology*

15 As an alternative to humanization, human antibodies can be generated. For example, it is now possible to produce transgenic animals (*e.g.*, mice) that are capable, upon immunization, of producing a full repertoire of human antibodies in the absence of endogenous immunoglobulin production. For example, it has been described that the homozygous deletion of the antibody heavy-chain joining region ( $J_H$ ) gene in chimeric and germ-line mutant mice results in complete inhibition of endogenous antibody production.

20 Transfer of the human germ-line immunoglobulin gene array into such germ-line mutant mice will result in the production of human antibodies upon antigen challenge. See, *e.g.*, Jakobovits *et al.*, *Proc. Natl. Acad. Sci. USA*, 90:2551 (1993); Jakobovits *et al.*, *Nature*, 362:255-258 (1993); Bruggemann *et al.*, *Year in Immuno.*, 7:33 (1993); U.S. Patent Nos. 5,545,806, 5,569,825, 5,591,669 (all of GenPharm); 5,545,807; and WO 97/17852.

25 Alternatively, phage display technology (McCafferty *et al.*, *Nature* 348:552-553 [1990]) can be used to produce human antibodies and antibody fragments *in vitro*, from immunoglobulin variable (V) domain gene repertoires from unimmunized donors. According to this technique, antibody V domain genes are cloned in-frame into either a major or minor coat protein gene of a filamentous bacteriophage, such as M13 or fd, and displayed as functional antibody fragments on the surface of the phage particle. Because the 30 filamentous particle contains a single-stranded DNA copy of the phage genome, selections based on the functional properties of the antibody also result in selection of the gene encoding the antibody exhibiting those properties. Thus, the phage mimics some of the properties of the B-cell. Phage display can be performed in a variety of formats, reviewed in, *e.g.*, Johnson, Kevin S. and Chiswell, David J., *Current Opinion in Structural Biology* 3:564-571 (1993). Several sources of V-gene segments can be used for phage 35 display. Clackson *et al.*, *Nature*, 352:624-628 (1991) isolated a diverse array of anti-oxazolone antibodies from a small random combinatorial library of V genes derived from the spleens of immunized mice. A repertoire of V genes from unimmunized human donors can be constructed and antibodies to a diverse array of antigens (including self-antigens) can be isolated essentially following the techniques described by Marks *et al.*, *J. Mol. Biol.* 222:581-597 (1991), or Griffith *et al.*, *EMBO J.* 12:725-734 (1993). See, also, U.S. 40 Patent Nos. 5,565,332 and 5,573,905.

As discussed above, human antibodies may also be generated by *in vitro* activated B cells (see U.S. Patents 5,567,610 and 5,229,275).

5        *Antibody fragments*

In certain circumstances there are advantages of using antibody fragments, rather than whole antibodies. The smaller size of the fragments allows for rapid clearance, and may lead to improved access to solid tumors.

Various techniques have been developed for the production of antibody fragments. Traditionally, 10 these fragments were derived via proteolytic digestion of intact antibodies (see, e.g., Morimoto *et al.*, *Journal of Biochemical and Biophysical Methods* 24:107-117 (1992); and Brennan *et al.*, *Science*, 229:81 (1985)). However, these fragments can now be produced directly by recombinant host cells. Fab, Fv and ScFv antibody fragments can all be expressed in and secreted from *E. coli*, thus allowing the facile 15 production of large amounts of these fragments. Antibody fragments can be isolated from the antibody phage libraries discussed above. Alternatively, Fab'-SH fragments can be directly recovered from *E. coli* and chemically coupled to form F(ab')<sub>2</sub> fragments (Carter *et al.*, *Bio/Technology* 10:163-167 (1992)). According to another approach, F(ab')<sub>2</sub> fragments can be isolated directly from recombinant host cell culture. 20 Fab and F(ab')<sub>2</sub> fragment with increased in vivo half-life comprising a salvage receptor binding epitope residues are described in U.S. Patent No. 5,869,046. Other techniques for the production of antibody fragments will be apparent to the skilled practitioner. In other embodiments, the antibody of choice is a single chain Fv fragment (scFv). See WO 93/16185; U.S. Patent No. 5,571,894; and U.S. Patent No. 25 5,587,458. Fv and sFv are the only species with intact combining sites that are devoid of constant regions; thus, they are suitable for reduced nonspecific binding during in vivo use. sFv fusion proteins may be constructed to yield fusion of an effector protein at either the amino or the carboxy terminus of an sFv. See Antibody Engineering, ed. Borrebaeck, supra. The antibody fragment may also be a "linear antibody", e.g., as described in U.S. Patent 5,641,870 for example. Such linear antibody fragments may be monospecific or bispecific.

*Bispecific antibodies*

30        Bispecific antibodies are antibodies that have binding specificities for at least two different epitopes. Exemplary bispecific antibodies may bind to two different epitopes of the CD20 protein. Other such antibodies may combine a CD20 binding site with a binding site for another protein. Alternatively, an anti-CD20 arm may be combined with an arm which binds to a triggering molecule on a leukocyte such as a T-cell receptor molecule (e.g. CD3), or Fc receptors for IgG (FcγR), such as FcγRI (CD64), FcγRII (CD32) 35 and FcγRIII (CD16), or NKG2D or other NK cell activating ligand, so as to focus and localize cellular defense mechanisms to the CD20-expressing cell. Bispecific antibodies may also be used to localize cytotoxic agents to cells which express CD20. These antibodies possess a CD20-binding arm and an arm which binds the cytotoxic agent (e.g. saporin, anti-interferon- $\alpha$ , vinca alkaloid, ricin A chain, methotrexate or radioactive isotope hapten). Bispecific antibodies can be prepared as full length antibodies or antibody 40 fragments (e.g. F(ab')<sub>2</sub> bispecific antibodies).

WO 96/16673 describes a bispecific anti-ErbB2/anti-FcγRIII antibody and U.S. Patent No. 5,837,234 discloses a bispecific anti-ErbB2/anti-FcγRI antibody. A bispecific anti-ErbB2/Fc $\alpha$  antibody is shown in WO98/02463. U.S. Patent No. 5,821,337 teaches a bispecific anti-ErbB2/anti-CD3 antibody.

5 Methods for making bispecific antibodies are known in the art. Traditional production of full length bispecific antibodies is based on the co-expression of two immunoglobulin heavy chain-light chain pairs, where the two chains have different specificities (Millstein *et al.*, *Nature*, 305:537-539 (1983)).  
Because of the random assortment of immunoglobulin heavy and light chains, these hybridomas  
10 (quadromas) produce a potential mixture of 10 different antibody molecules, of which only one has the correct bispecific structure. Purification of the correct molecule, which is usually done by affinity chromatography steps, is rather cumbersome, and the product yields are low. Similar procedures are disclosed in WO 93/08829, and in Traunecker *et al.*, *EMBO J.*, 10:3655-3659 (1991).

15 According to a different approach, antibody variable domains with the desired binding specificities (antibody-antigen combining sites) are fused to immunoglobulin constant domain sequences. Preferably, the fusion is with an Ig heavy chain constant domain, comprising at least part of the hinge, C<sub>H</sub>2, and C<sub>H</sub>3 regions. It is preferred to have the first heavy-chain constant region (C<sub>H</sub>1) containing the site necessary for light chain bonding, present in at least one of the fusions. DNAs encoding the immunoglobulin heavy chain fusions and, if desired, the immunoglobulin light chain, are inserted into separate expression vectors, and are co-transfected into a suitable host cell. This provides for greater flexibility in adjusting the mutual  
20 proportions of the three polypeptide fragments in embodiments when unequal ratios of the three polypeptide chains used in the construction provide the optimum yield of the desired bispecific antibody. It is, however, possible to insert the coding sequences for two or all three polypeptide chains into a single expression vector when the expression of at least two polypeptide chains in equal ratios results in high yields or when the ratios have no significant affect on the yield of the desired chain combination.

25 In a preferred embodiment of this approach, the bispecific antibodies are composed of a hybrid immunoglobulin heavy chain with a first binding specificity in one arm, and a hybrid immunoglobulin heavy chain-light chain pair (providing a second binding specificity) in the other arm. It was found that this asymmetric structure facilitates the separation of the desired bispecific compound from unwanted immunoglobulin chain combinations, as the presence of an immunoglobulin light chain in only one half of  
30 the bispecific molecule provides for a facile way of separation. This approach is disclosed in WO 94/04690. For further details of generating bispecific antibodies see, for example, Suresh *et al.*, *Methods in Enzymology*, 121:210 (1986).

According to another approach described in U.S. Patent No. 5,731,168, the interface between a pair of antibody molecules can be engineered to maximize the percentage of heterodimers which are recovered  
35 from recombinant cell culture. The preferred interface comprises at least a part of the C<sub>H</sub>3 domain. In this method, one or more small amino acid side chains from the interface of the first antibody molecule are replaced with larger side chains (*e.g.* tyrosine or tryptophan). Compensatory "cavities" of identical or similar size to the large side chain(s) are created on the interface of the second antibody molecule by replacing large amino acid side chains with smaller ones (*e.g.* alanine or threonine). This provides a  
40 mechanism for increasing the yield of the heterodimer over other unwanted end-products such as homodimers.

Bispecific antibodies include cross-linked or "heteroconjugate" antibodies. For example, one of the antibodies in the heteroconjugate can be coupled to avidin, the other to biotin. Such antibodies have, for example, been proposed to target immune system cells to unwanted cells (U.S. Patent No. 4,676,980), and

5 for treatment of HIV infection (WO 91/00360, WO 92/200373, and EP 03089). Heteroconjugate antibodies may be made using any convenient cross-linking methods. Suitable cross-linking agents are well known in the art, and are disclosed in U.S. Patent No. 4,676,980, along with a number of cross-linking techniques.

Techniques for generating bispecific antibodies from antibody fragments have also been described in the literature. For example, bispecific antibodies can be prepared using chemical linkage. Brennan *et al.*, 10 *Science*, 229: 81 (1985) describe a procedure wherein intact antibodies are proteolytically cleaved to generate F(ab')<sub>2</sub> fragments. These fragments are reduced in the presence of the dithiol complexing agent, sodium arsenite, to stabilize vicinal dithiols and prevent intermolecular disulfide formation. The Fab' fragments generated are then converted to thionitrobenzoate (TNB) derivatives. One of the Fab'-TNB derivatives is then reconverted to the Fab'-thiol by reduction with mercaptoethylamine and is mixed with an 15 equimolar amount of the other Fab'-TNB derivative to form the bispecific antibody. The bispecific antibodies produced can be used as agents for the selective immobilization of enzymes.

Recent progress has facilitated the direct recovery of Fab'-SH fragments from *E. coli*, which can be chemically coupled to form bispecific antibodies. Shalaby *et al.*, *J. Exp. Med.*, 175: 217-225 (1992) describe the production of a fully humanized bispecific antibody F(ab')<sub>2</sub> molecule. Each Fab' fragment was separately 20 secreted from *E. coli* and subjected to directed chemical coupling *in vitro* to form the bispecific antibody. The bispecific antibody thus formed was able to bind to cells overexpressing the ErbB2 receptor and normal human T cells, as well as trigger the lytic activity of human cytotoxic lymphocytes against human breast tumor targets.

Various techniques for making and isolating bispecific antibody fragments directly from 25 recombinant cell culture have also been described. For example, bispecific antibodies have been produced using leucine zippers. Kostelny *et al.*, *J. Immunol.*, 148(5):1547-1553 (1992). The leucine zipper peptides from the Fos and Jun proteins were linked to the Fab' portions of two different antibodies by gene fusion. The antibody homodimers were reduced at the hinge region to form monomers and then re-oxidized to form 30 the antibody heterodimers. This method can also be utilized for the production of antibody homodimers. The "diabody" technology described by Hollinger *et al.*, *Proc. Natl. Acad. Sci. USA*, 90:6444-6448 (1993) has provided an alternative mechanism for making bispecific antibody fragments. The fragments comprise a 35 V<sub>H</sub> connected to a V<sub>L</sub> by a linker which is too short to allow pairing between the two domains on the same chain. Accordingly, the V<sub>H</sub> and V<sub>L</sub> domains of one fragment are forced to pair with the complementary V<sub>L</sub> and V<sub>H</sub> domains of another fragment, thereby forming two antigen-binding sites. Another strategy for making bispecific antibody fragments by the use of single-chain Fv (sFv) dimers has also been reported. See Gruber *et al.*, *J. Immunol.*, 152:5368 (1994).

Antibodies with more than two valencies are contemplated. For example, trispecific antibodies can be prepared. Tutt *et al.* *J. Immunol.* 147: 60 (1991).

40 *Multivalent Antibodies*

A multivalent antibody may be internalized (and/or catabolized) faster than a bivalent antibody by a cell expressing an antigen to which the antibodies bind. The antibodies of the present invention can be multivalent antibodies (which are other than of the IgM class) with three or more antigen binding sites (e.g. tetravalent antibodies), which can be readily produced by recombinant expression of nucleic acid encoding

5 the polypeptide chains of the antibody. The multivalent antibody can comprise a dimerization domain and three or more antigen binding sites. The preferred dimerization domain comprises (or consists of) an Fc region or a hinge region. In this scenario, the antibody will comprise an Fc region and three or more antigen binding sites amino-terminal to the Fc region. The preferred multivalent antibody herein comprises (or consists of) three to about eight, but preferably four, antigen binding sites. The multivalent antibody  
10 comprises at least one polypeptide chain (and preferably two polypeptide chains), wherein the polypeptide chain(s) comprise two or more variable domains. For instance, the polypeptide chain(s) may comprise VD1-(X1)<sub>n</sub>-VD2-(X2)<sub>n</sub>-Fc, wherein VD1 is a first variable domain, VD2 is a second variable domain, Fc is one polypeptide chain of an Fc region, X1 and X2 represent an amino acid or polypeptide, and n is 0 or 1. For instance, the polypeptide chain(s) may comprise: VH-CH1-flexible linker-VH-CH1-Fc region chain; or VH-  
15 CH1-VH-CH1-Fc region chain. The multivalent antibody herein preferably further comprises at least two (and preferably four) light chain variable domain polypeptides. The multivalent antibody herein may, for instance, comprise from about two to about eight light chain variable domain polypeptides. The light chain variable domain polypeptides contemplated here comprise a light chain variable domain and, optionally, further comprise a CL domain.

20

*Other amino acid sequence modifications*

Amino acid sequence modification(s) of the CD20 binding antibodies described herein are contemplated. For example, it may be desirable to improve the binding affinity and/or other biological properties of the antibody. Amino acid sequence variants of the anti-CD20 antibody are prepared by  
25 introducing appropriate nucleotide changes into the anti-CD20 antibody nucleic acid, or by peptide synthesis. Such modifications include, for example, deletions from, and/or insertions into and/or substitutions of, residues within the amino acid sequences of the anti-CD20 antibody. Any combination of deletion, insertion, and substitution is made to arrive at the final construct, provided that the final construct possesses the desired characteristics. The amino acid changes also may alter post-translational processes of  
30 the anti-CD20 antibody, such as changing the number or position of glycosylation sites.

A useful method for identification of certain residues or regions of the anti-CD20 antibody that are preferred locations for mutagenesis is called "alanine scanning mutagenesis" as described by Cunningham and Wells in *Science*, 244:1081-1085 (1989). Here, a residue or group of target residues are identified (e.g., charged residues such as arg, asp, his, lys, and glu) and replaced by a neutral or negatively charged amino acid (most preferably alanine or polyalanine) to affect the interaction of the amino acids with CD20 antigen.  
35 Those amino acid locations demonstrating functional sensitivity to the substitutions then are refined by introducing further or other variants at, or for, the sites of substitution. Thus, while the site for introducing an amino acid sequence variation is predetermined, the nature of the mutation *per se* need not be predetermined. For example, to analyze the performance of a mutation at a given site, ala scanning or  
40 random mutagenesis is conducted at the target codon or region and the expressed anti-CD20 antibody variants are screened for the desired activity.

Amino acid sequence insertions include amino- and/or carboxyl-terminal fusions ranging in length from one residue to polypeptides containing a hundred or more residues, as well as intrasequence insertions of single or multiple amino acid residues. Examples of terminal insertions include an anti-CD20 antibody

5 with an N-terminal methionyl residue or the antibody fused to a cytotoxic polypeptide. Other insertional variants of the anti-CD20 antibody molecule include the fusion to the N- or C-terminus of the anti-CD20 antibody to an enzyme (*e.g.* for ADEPT) or a polypeptide which increases the serum half-life of the antibody.

Another type of variant is an amino acid substitution variant. These variants have at least one 10 amino acid residue in the anti-CD20 antibody molecule replaced by a different residue. The sites of greatest interest for substitutional mutagenesis include the hypervariable regions, but FR alterations are also contemplated. Conservative substitutions are shown in the Table below under the heading of "preferred substitutions". If such substitutions result in a change in biological activity, then more substantial changes, 15 denominated "exemplary substitutions" in the Table, or as further described below in reference to amino acid classes, may be introduced and the products screened.

*TABLE of Amino Acid Substitutions*

Original Residue	Exemplary Substitutions	Preferred Substitutions
Ala (A)	val; leu; ile	val
Arg (R)	lys; gln; asn	lys
Asn (N)	gln; his; asp, lys; arg	gln
Asp (D)	glu; asn	glu
Cys (C)	ser; ala	ser
Gln (Q)	asn; glu	asn
Glu (E)	asp; gln	asp
Gly (G)	ala	ala
His (H)	asn; gln; lys; arg	arg
Ile (I)	leu; val; met; ala; phe; norleucine	leu
Leu (L)	norleucine; ile; val; met; ala; phe	ile
Lys (K)	arg; gln; asn	arg
Met (M)	leu; phe; ile	leu
Phe (F)	leu; val; ile; ala; tyr	tyr
Pro (P)	ala	ala
Ser (S)	thr	thr
Thr (T)	ser	ser
Trp (W)	tyr; phe	tyr
Tyr (Y)	trp; phe; thr; ser	phe
Val (V)	ile; leu; met; phe; ala; norleucine	leu

5

Substantial modifications in the biological properties of the antibody are accomplished by selecting substitutions that differ significantly in their effect on maintaining (a) the structure of the polypeptide backbone in the area of the substitution, for example, as a sheet or helical conformation, (b) the charge or hydrophobicity of the molecule at the target site, or (c) the bulk of the side chain. Naturally occurring

10 residues are divided into groups based on common side-chain properties:

- (1) hydrophobic: norleucine, met, ala, val, leu, ile;
- (2) neutral hydrophilic: cys, ser, thr;
- (3) acidic: asp, glu;
- (4) basic: asn, gln, his, lys, arg;
- (5) residues that influence chain orientation: gly, pro; and
- (6) aromatic: trp, tyr, phe.

15

Non-conservative substitutions will entail exchanging a member of one of these classes for another class.

Any cysteine residue not involved in maintaining the proper conformation of the anti-CD20  
20 antibody also may be substituted, generally with serine, to improve the oxidative stability of the molecule and prevent aberrant crosslinking. Conversely, cysteine bond(s) may be added to the antibody to improve its stability (particularly where the antibody is an antibody fragment such as an Fv fragment).

A particularly preferred type of substitutional variant involves substituting one or more hypervariable region residues of a parent antibody (e.g. a humanized or human antibody). Generally, the  
25 resulting variant(s) selected for further development will have improved biological properties relative to the parent antibody from which they are generated. A convenient way for generating such substitutional variants involves affinity maturation using phage display. Briefly, several hypervariable region sites (e.g. 6-7 sites) are mutated to generate all possible amino substitutions at each site. The antibody variants thus generated are displayed in a monovalent fashion from filamentous phage particles as fusions to the gene III  
30 product of M13 packaged within each particle. The phage-displayed variants are then screened for their biological activity (e.g. binding affinity) as herein disclosed. In order to identify candidate hypervariable region sites for modification, alanine scanning mutagenesis can be performed to identify hypervariable region residues contributing significantly to antigen binding. Alternatively, or additionally, it may be beneficial to analyze a crystal structure of the antigen-antibody complex to identify contact points between  
35 the antibody and human CD20. Such contact residues and neighboring residues are candidates for substitution according to the techniques elaborated herein. Once such variants are generated, the panel of variants is subjected to screening as described herein and antibodies with superior properties in one or more relevant assays may be selected for further development.

Another type of amino acid variant of the antibody alters the original glycosylation pattern of the  
40 antibody. By altering is meant deleting one or more carbohydrate moieties found in the antibody, and/or adding one or more glycosylation sites that are not present in the antibody.

Glycosylation of antibodies is typically either N-linked or O-linked. N-linked refers to the attachment of the carbohydrate moiety to the side chain of an asparagine residue. The tripeptide sequences asparagine-X-serine and asparagine-X-threonine, where X is any amino acid except proline, are the

5 recognition sequences for enzymatic attachment of the carbohydrate moiety to the asparagine side chain. Thus, the presence of either of these tripeptide sequences in a polypeptide creates a potential glycosylation site. O-linked glycosylation refers to the attachment of one of the sugars N-acetylglucosamine, galactose, or xylose to a hydroxyamino acid, most commonly serine or threonine, although 5-hydroxyproline or 5-hydroxylysine may also be used.

10 Addition of glycosylation sites to the antibody is conveniently accomplished by altering the amino acid sequence such that it contains one or more of the above-described tripeptide sequences (for N-linked glycosylation sites). The alteration may also be made by the addition of, or substitution by, one or more serine or threonine residues to the sequence of the original antibody (for O-linked glycosylation sites).

15 Nucleic acid molecules encoding amino acid sequence variants of the anti-CD20 antibody are prepared by a variety of methods known in the art. These methods include, but are not limited to, isolation from a natural source (in the case of naturally occurring amino acid sequence variants) or preparation by oligonucleotide-mediated (or site-directed) mutagenesis, PCR mutagenesis, and cassette mutagenesis of an earlier prepared variant or a non-variant version of the anti-CD20 antibody.

20 It may be desirable to modify the antibody of the invention with respect to effector function, e.g. so as to enhance antigen-dependent cell-mediated cytotoxicity (ADCC) and/or complement dependent cytotoxicity (CDC) of the antibody. This may be achieved by introducing one or more amino acid substitutions in an Fc region of the antibody. Alternatively or additionally, cysteine residue(s) may be introduced in the Fc region, thereby allowing interchain disulfide bond formation in this region. The homodimeric antibody thus generated may have improved internalization capability and/or increased 25 complement-mediated cell killing and antibody-dependent cellular cytotoxicity (ADCC). See Caron *et al.*, *J. Exp Med.* 176:1191-1195 (1992) and Shope, B. J. *Immunol.* 148:2918-2922 (1992). Homodimeric antibodies with enhanced anti-tumor activity may also be prepared using heterobifunctional cross-linkers as described in Wolff *et al.* *Cancer Research* 53:2560-2565 (1993). Alternatively, an antibody can be engineered which has dual Fc regions and may thereby have enhanced complement mediated lysis and 30 ADCC capabilities. See Stevenson *et al.* *Anti-Cancer Drug Design* 3:219-230 (1989).

35 To increase the serum half life of the antibody, one may incorporate a salvage receptor binding epitope into the antibody (especially an antibody fragment) as described in U.S. Patent 5,739,277, for example. As used herein, the term "salvage receptor binding epitope" refers to an epitope of the Fc region of an IgG molecule (e.g., IgG<sub>1</sub>, IgG<sub>2</sub>, IgG<sub>3</sub>, or IgG<sub>4</sub>) that is responsible for increasing the *in vivo* serum half-life of the IgG molecule.

#### *Other antibody modifications*

40 Other modifications of the antibody are contemplated herein. For example, the antibody may be linked to one of a variety of nonproteinaceous polymers, e.g., polyethylene glycol, polypropylene glycol, polyoxyalkylenes, or copolymers of polyethylene glycol and polypropylene glycol. The antibody also may be entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization (for example, hydroxymethylcellulose or gelatin-microcapsules and poly-(methylmethacrylate) microcapsules, respectively), in colloidal drug delivery systems (for example,

- 5 liposomes, albumin microspheres, microemulsions, nano-particles and nanocapsules), or in macroemulsions. Such techniques are disclosed in *Remington's Pharmaceutical Sciences*, 16th edition, Oslo, A., Ed., (1980).

*Screening for antibodies with the desired properties*

Antibodies with certain biological characteristics may be selected as described in the Experimental Examples.

The growth inhibitory effects of an anti-CD20 antibody of the invention may be assessed by methods known in the art, e.g., using cells which express CD20 either endogenously or following transfection with the CD20 gene. For example, tumor cell lines and CD20-transfected cells may be treated with an anti-CD20 monoclonal antibody of the invention at various concentrations for a few days (e.g., 2-7) days and stained with crystal violet or MTT or analyzed by some other colorimetric assay. Another method of measuring proliferation would be by comparing  $^3\text{H}$ -thymidine uptake by the cells treated in the presence or absence an anti-CD20 antibody of the invention. After antibody treatment, the cells are harvested and the amount of radioactivity incorporated into the DNA quantitated in a scintillation counter. Appropriate positive controls include treatment of a selected cell line with a growth inhibitory antibody known to inhibit growth of that cell line.

To select for antibodies which induce cell death, loss of membrane integrity as indicated by, e.g., propidium iodide (PI), trypan blue or 7AAD uptake may be assessed relative to control. A PI uptake assay can be performed in the absence of complement and immune effector cells. CD20-expressing tumor cells are incubated with medium alone or medium containing of the appropriate monoclonal antibody at e.g., about 10 $\mu\text{g}/\text{ml}$ . The cells are incubated for a 3 day time period. Following each treatment, cells are washed and aliquoted into 35 mm strainer-capped 12 x 75 tubes (1ml per tube, 3 tubes per treatment group) for removal of cell clumps. Tubes then receive PI (10 $\mu\text{g}/\text{ml}$ ). Samples may be analyzed using a FACSCAN™ flow cytometer and FACSCONVERT™ CellQuest software (Becton Dickinson). Those antibodies which induce statistically significant levels of cell death as determined by PI uptake may be selected as cell death-inducing antibodies.

To screen for antibodies which bind to an epitope on CD20 bound by an antibody of interest, a routine cross-blocking assay such as that described in *Antibodies, A Laboratory Manual*, Cold Spring Harbor Laboratory, Ed Harlow and David Lane (1988), can be performed. This assay can be used to determine if a test antibody binds the same site or epitope as an anti-CD20 antibody of the invention. Alternatively, or additionally, epitope mapping can be performed by methods known in the art. For example, the antibody sequence can be mutagenized such as by alanine scanning, to identify contact residues. The mutant antibody is initially tested for binding with polyclonal antibody to ensure proper folding. In a different method, peptides corresponding to different regions of CD20 can be used in competition assays with the test antibodies or with a test antibody and an antibody with a characterized or known epitope.

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**Vectors, Host Cells and Recombinant Methods**

The invention also provides an isolated nucleic acid encoding a humanized CD20 binding antibody, vectors and host cells comprising the nucleic acid, and recombinant techniques for the production of the antibody.

5 For recombinant production of the antibody, the nucleic acid encoding it is isolated and inserted into a replicable vector for further cloning (amplification of the DNA) or for expression. DNA encoding the monoclonal antibody is readily isolated and sequenced using conventional procedures (*e.g.*, by using oligonucleotide probes that are capable of binding specifically to genes encoding the heavy and light chains of the antibody). Many vectors are available. The vector components generally include, but are not limited  
10 to, one or more of the following: a signal sequence, an origin of replication, one or more marker genes, an enhancer element, a promoter, and a transcription termination sequence.

(i) *Signal sequence component*

The CD20 binding antibody of this invention may be produced recombinantly not only directly, but also as a fusion polypeptide with a heterologous polypeptide, which is preferably a signal sequence or other  
15 polypeptide having a specific cleavage site at the N-terminus of the mature protein or polypeptide. The heterologous signal sequence selected preferably is one that is recognized and processed (*i.e.*, cleaved by a signal peptidase) by the host cell. For prokaryotic host cells that do not recognize and process the native CD20 binding antibody signal sequence, the signal sequence is substituted by a prokaryotic signal sequence selected, for example, from the group of the alkaline phosphatase, penicillinase, lpp, or heat-stable  
20 enterotoxin II leaders. For yeast secretion the native signal sequence may be substituted by, *e.g.*, the yeast invertase leader,  $\alpha$  factor leader (including *Saccharomyces* and *Kluyveromyces*  $\alpha$ -factor leaders), or acid phosphatase leader, the *C. albicans* glucoamylase leader, or the signal described in WO 90/13646. In mammalian cell expression, mammalian signal sequences as well as viral secretory leaders, for example, the herpes simplex gD signal, are available.

25 The DNA for such precursor region is ligated in reading frame to DNA encoding the CD20 binding antibody.

(ii) *Origin of replication*

Both expression and cloning vectors contain a nucleic acid sequence that enables the vector to replicate in one or more selected host cells. Generally, in cloning vectors this sequence is one that enables  
30 the vector to replicate independently of the host chromosomal DNA, and includes origins of replication or autonomously replicating sequences. Such sequences are well known for a variety of bacteria, yeast, and viruses. The origin of replication from the plasmid pBR322 is suitable for most Gram-negative bacteria, the 2 $\mu$  plasmid origin is suitable for yeast, and various viral origins (SV40, polyoma, adenovirus, VSV or BPV) are useful for cloning vectors in mammalian cells. Generally, the origin of replication component is not  
35 needed for mammalian expression vectors (the SV40 origin may typically be used only because it contains the early promoter).

(iii) *Selection gene component*

Expression and cloning vectors may contain a selection gene, also termed a selectable marker. Typical selection genes encode proteins that (a) confer resistance to antibiotics or other toxins, *e.g.*, ampicillin, neomycin, methotrexate, or tetracycline, (b) complement auxotrophic deficiencies, or (c) supply critical nutrients not available from complex media, *e.g.*, the gene encoding D-alanine racemase for *Bacilli*.

One example of a selection scheme utilizes a drug to arrest growth of a host cell. Those cells that are successfully transformed with a heterologous gene produce a protein conferring drug resistance and thus

5 survive the selection regimen. Examples of such dominant selection use the drugs neomycin, mycophenolic acid and hygromycin.

Another example of suitable selectable markers for mammalian cells are those that enable the identification of cells competent to take up the CD20 binding antibody nucleic acid, such as DHFR, thymidine kinase, metallothionein-I and -II, preferably primate metallothionein genes, adenosine deaminase, 10 ornithine decarboxylase, etc.

For example, cells transformed with the DHFR selection gene are first identified by culturing all of the transformants in a culture medium that contains methotrexate (Mtx), a competitive antagonist of DHFR. An appropriate host cell when wild-type DHFR is employed is the Chinese hamster ovary (CHO) cell line deficient in DHFR activity (e.g., ATCC CRL-9096).

15 Alternatively, host cells (particularly wild-type hosts that contain endogenous DHFR) transformed or co-transformed with DNA sequences encoding CD20 binding antibody, wild-type DHFR protein, and another selectable marker such as aminoglycoside 3'-phosphotransferase (APH) can be selected by cell growth in medium containing a selection agent for the selectable marker such as an aminoglycosidic antibiotic, e.g., kanamycin, neomycin, or G418. See U.S. Patent No. 4,965,199.

20 A suitable selection gene for use in yeast is the *trp1* gene present in the yeast plasmid YRp7 (Stinchcomb *et al.*, *Nature*, 282:39 (1979)). The *trp1* gene provides a selection marker for a mutant strain of yeast lacking the ability to grow in tryptophan, for example, ATCC No. 44076 or PEP4-1. Jones, *Genetics*, 85:12 (1977). The presence of the *trp1* lesion in the yeast host cell genome then provides an effective environment for detecting transformation by growth in the absence of tryptophan. Similarly, *Leu2*-deficient 25 yeast strains (ATCC 20,622 or 38,626) are complemented by known plasmids bearing the *Leu2* gene.

In addition, vectors derived from the 1.6  $\mu$ m circular plasmid pKD1 can be used for transformation of *Kluyveromyces* yeasts. Alternatively, an expression system for large-scale production of recombinant calf chymosin was reported for *K. lactis*. Van den Berg, *Bio/Technology*, 8:135 (1990). Stable multi-copy expression vectors for secretion of mature recombinant human serum albumin by industrial strains of 30 *Kluyveromyces* have also been disclosed. Fleer *et al.*, *Bio/Technology*, 9:968-975 (1991).

(iv) *Promoter component*

Expression and cloning vectors usually contain a promoter that is recognized by the host organism and is operably linked to the nucleic acid encoding the CD20 binding antibody. Promoters suitable for use with prokaryotic hosts include the *phoA* promoter,  $\beta$ -lactamase and lactose promoter systems, alkaline phosphatase promoter, a tryptophan (*trp*) promoter system, and hybrid promoters such as the tac promoter. 35 However, other known bacterial promoters are suitable. Promoters for use in bacterial systems also will contain a Shine-Dalgarno (S.D.) sequence operably linked to the DNA encoding the CD20 binding antibody.

Promoter sequences are known for eukaryotes. Virtually all eukaryotic genes have an AT-rich region located approximately 25 to 30 bases upstream from the site where transcription is initiated. Another 40 sequence found 70 to 80 bases upstream from the start of transcription of many genes is a CNCAAT region where N may be any nucleotide. At the 3' end of most eukaryotic genes is an AATAAA sequence that may be the signal for addition of the poly A tail to the 3' end of the coding sequence. All of these sequences are suitably inserted into eukaryotic expression vectors.

5 Examples of suitable promoter sequences for use with yeast hosts include the promoters for 3-phosphoglycerate kinase or other glycolytic enzymes, such as enolase, glyceraldehyde-3-phosphate dehydrogenase, hexokinase, pyruvate decarboxylase, phosphofructokinase, glucose-6-phosphate isomerase, 3-phosphoglycerate mutase, pyruvate kinase, triosephosphate isomerase, phosphoglucose isomerase, and glucokinase.

10 Other yeast promoters, which are inducible promoters having the additional advantage of transcription controlled by growth conditions, are the promoter regions for alcohol dehydrogenase 2, isocytochrome C, acid phosphatase, degradative enzymes associated with nitrogen metabolism, metallothionein, glyceraldehyde-3-phosphate dehydrogenase, and enzymes responsible for maltose and galactose utilization. Suitable vectors and promoters for use in yeast expression are further described in EP 15 73,657. Yeast enhancers also are advantageously used with yeast promoters.

CD20 binding antibody transcription from vectors in mammalian host cells is controlled, for example, by promoters obtained from the genomes of viruses such as polyoma virus, fowlpox virus, adenovirus (such as Adenovirus 2), bovine papilloma virus, avian sarcoma virus, cytomegalovirus, a retrovirus, hepatitis-B virus and most preferably Simian Virus 40 (SV40), from heterologous mammalian 20 promoters, e.g., the actin promoter or an immunoglobulin promoter, from heat-shock promoters, provided such promoters are compatible with the host cell systems.

The early and late promoters of the SV40 virus are conveniently obtained as an SV40 restriction fragment that also contains the SV40 viral origin of replication. The immediate early promoter of the human cytomegalovirus is conveniently obtained as a HindIII E restriction fragment. A system for expressing DNA 25 in mammalian hosts using the bovine papilloma virus as a vector is disclosed in U.S. Patent No. 4,419,446. A modification of this system is described in U.S. Patent No. 4,601,978. See also Reyes *et al.*, *Nature* 297:598-601 (1982) on expression of human  $\beta$ -interferon cDNA in mouse cells under the control of a thymidine kinase promoter from herpes simplex virus. Alternatively, the Rous Sarcoma Virus long terminal repeat can be used as the promoter.

30 (v) *Enhancer element component*

Transcription of a DNA encoding the CD20 binding antibody of this invention by higher eukaryotes is often increased by inserting an enhancer sequence into the vector. Many enhancer sequences are now known from mammalian genes (globin, elastase, albumin,  $\alpha$ -fetoprotein, and insulin). Typically, however, one will use an enhancer from a eukaryotic cell virus. Examples include the SV40 enhancer on the late side 35 of the replication origin (bp 100-270), the cytomegalovirus early promoter enhancer, the polyoma enhancer on the late side of the replication origin, and adenovirus enhancers. See also Yaniv, *Nature* 297:17-18 (1982) on enhancing elements for activation of eukaryotic promoters. The enhancer may be spliced into the vector at a position 5' or 3' to the CD20 binding antibody-encoding sequence, but is preferably located at a site 5' from the promoter.

40 (vi) *Transcription termination component*

Expression vectors used in eukaryotic host cells (yeast, fungi, insect, plant, animal, human, or nucleated cells from other multicellular organisms) will also contain sequences necessary for the termination of transcription and for stabilizing the mRNA. Such sequences are commonly available from the 5' and, occasionally 3', untranslated regions of eukaryotic or viral DNAs or cDNAs. These regions contain

5 nucleotide segments transcribed as polyadenylated fragments in the untranslated portion of the mRNA encoding CD20 binding antibody. One useful transcription termination component is the bovine growth hormone polyadenylation region. See WO94/11026 and the expression vector disclosed therein.

(vii) *Selection and transformation of host cells*

Suitable host cells for cloning or expressing the DNA in the vectors herein are the prokaryote, yeast, or higher eukaryote cells described above. Suitable prokaryotes for this purpose include eubacteria, such as Gram-negative or Gram-positive organisms, for example, Enterobacteriaceae such as *Escherichia*, e.g., *E. coli*, *Enterobacter*, *Erwinia*, *Klebsiella*, *Proteus*, *Salmonella*, e.g., *Salmonella typhimurium*, *Serratia*, e.g., *Serratia marcescans*, and *Shigella*, as well as *Bacilli* such as *B. subtilis* and *B. licheniformis* (e.g., *B. licheniformis* 41P disclosed in DD 266,710 published 12 April 1989), *Pseudomonas* such as *P. aeruginosa*, and *Streptomyces*. One preferred *E. coli* cloning host is *E. coli* 294 (ATCC 31,446), although other strains such as *E. coli* B, *E. coli* X1776 (ATCC 31,537), and *E. coli* W3110 (ATCC 27,325) are suitable. These examples are illustrative rather than limiting.

Full length antibody, antibody fragments, and antibody fusion proteins can be produced in bacteria, in particular when glycosylation and Fc effector function are not needed, such as when the therapeutic antibody is conjugated to a cytotoxic agent (e.g., a toxin) and the immunoonjugate by itself shows effectiveness in tumor cell destruction. Full length antibodies have greater half life in circulation. Production in *E. coli* is faster and more cost efficient. For expression of antibody fragments and polypeptides in bacteria, see, e.g., U.S. 5,648,237 (Carter et. al.), U.S. 5,789,199 (Joly et al.), and U.S. 5,840,523 (Simmons et al.) which describes translation initiation region (TIR) and signal sequences for optimizing expression and secretion, these patents incorporated herein by reference. After expression, the antibody is isolated from the *E. coli* cell paste in a soluble fraction and can be purified through, e.g., a protein A or G column depending on the isotype. Final purification can be carried out similar to the process for purifying antibody expressed e.g., in CHO cells.

In addition to prokaryotes, eukaryotic microbes such as filamentous fungi or yeast are suitable cloning or expression hosts for CD20 binding antibody-encoding vectors. *Saccharomyces cerevisiae*, or common baker's yeast, is the most commonly used among lower eukaryotic host microorganisms. However, a number of other genera, species, and strains are commonly available and useful herein, such as *Schizosaccharomyces pombe*; *Kluyveromyces* hosts such as, e.g., *K. lactis*, *K. fragilis* (ATCC 12,424), *K. bulgaricus* (ATCC 16,045), *K. wickeramii* (ATCC 24,178), *K. waltii* (ATCC 56,500), *K. drosophilaram* (ATCC 36,906), *K. thermotolerans*, and *K. marxianus*; *yarrowia* (EP 402,226); *Pichia pastoris* (EP 183,070); *Candida*; *Trichoderma reesia* (EP 244,234); *Neurospora crassa*; *Schwanniomyces* such as *Schwanniomyces occidentalis*; and filamentous fungi such as, e.g., *Neurospora*, *Penicillium*, *Tolypocladium*, and *Aspergillus* hosts such as *A. nidulans* and *A. niger*.

Suitable host cells for the expression of glycosylated CD20 binding antibody are derived from multicellular organisms. Examples of invertebrate cells include plant and insect cells. Numerous baculoviral strains and variants and corresponding permissive insect host cells from hosts such as *Spodoptera frugiperda* (caterpillar), *Aedes aegypti* (mosquito), *Aedes albopictus* (mosquito), *Drosophila melanogaster* (fruitfly), and *Bombyx mori* have been identified. A variety of viral strains for transfection are publicly available, e.g., the L-1 variant of *Autographa californica* NPV and the Bm-5 strain of *Bombyx mori*

5 NPV, and such viruses may be used as the virus herein according to the present invention, particularly for transfection of *Spodoptera frugiperda* cells.

Plant cell cultures of cotton, corn, potato, soybean, petunia, tomato, and tobacco can also be utilized as hosts.

However, interest has been greatest in vertebrate cells, and propagation of vertebrate cells in culture (tissue culture) has become a routine procedure. Examples of useful mammalian host cell lines are monkey kidney CV1 line transformed by SV40 (COS-7, ATCC CRL 1651); human embryonic kidney line (293 or 293 cells subcloned for growth in suspension culture, Graham *et al.*, *J. Gen Virol.* 36:59 (1977)) ; baby hamster kidney cells (BHK, ATCC CCL 10); Chinese hamster ovary cells/-DHFR (CHO, Urlaub *et al.*, *Proc. Natl. Acad. Sci. USA* 77:4216 (1980)) ; mouse sertoli cells (TM4, Mather, *Biol. Reprod.* 23:243-251 (1980) ); monkey kidney cells (CV1 ATCC CCL 70); African green monkey kidney cells (VERO-76, ATCC CRL-1587); human cervical carcinoma cells (HELA, ATCC CCL 2); canine kidney cells (MDCK, ATCC CCL 34); buffalo rat liver cells (BRL 3A, ATCC CRL 1442); human lung cells (W138, ATCC CCL 75); human liver cells (Hep G2, HB 8065); mouse mammary tumor (MMT 060562, ATCC CCL51); TRI cells (Mather *et al.*, *Annals N.Y. Acad. Sci.* 383:44-68 (1982)); MRC 5 cells; FS4 cells; and a human hepatoma line (Hep G2).

Host cells are transformed with the above-described expression or cloning vectors for CD20 binding antibody production and cultured in conventional nutrient media modified as appropriate for inducing promoters, selecting transformants, or amplifying the genes encoding the desired sequences.

(viii) *Culturing the host cells*

The host cells used to produce the CD20 binding antibody of this invention may be cultured in a variety of media. Commercially available media such as Ham's F10 (Sigma), Minimal Essential Medium ((MEM), (Sigma), RPMI-1640 (Sigma), and Dulbecco's Modified Eagle's Medium ((DMEM), Sigma) are suitable for culturing the host cells. In addition, any of the media described in Ham *et al.*, *Meth. Enz.* 58:44 (1979), Barnes *et al.*, *Anal. Biochem.* 102:255 (1980), U.S. Pat. Nos. 4,767,704; 4,657,866; 4,927,762; 4,560,655; or 5,122,469; WO 90/03430; WO 87/00195; or U.S. Patent Re. 30,985 may be used as culture media for the host cells. Any of these media may be supplemented as necessary with hormones and/or other growth factors (such as insulin, transferrin, or epidermal growth factor), salts (such as sodium chloride, calcium, magnesium, and phosphate), buffers (such as HEPES), nucleotides (such as adenosine and thymidine), antibiotics (such as GENTAMYCIN™ drug), trace elements (defined as inorganic compounds usually present at final concentrations in the micromolar range), and glucose or an equivalent energy source. Any other necessary supplements may also be included at appropriate concentrations that would be known to those skilled in the art. The culture conditions, such as temperature, pH, and the like, are those previously used with the host cell selected for expression, and will be apparent to the ordinarily skilled artisan.

(ix) *Purification of antibody*

When using recombinant techniques, the antibody can be produced intracellularly, in the periplasmic space, or directly secreted into the medium. If the antibody is produced intracellularly, as a first step, the particulate debris, either host cells or lysed fragments, are removed, for example, by centrifugation or ultrafiltration. Carter *et al.*, *Bio/Technology* 10:163-167 (1992) describe a procedure for isolating antibodies which are secreted to the periplasmic space of *E. coli*. Briefly, cell paste is thawed in the

5 presence of sodium acetate (pH 3.5), EDTA, and phenylmethylsulfonylfluoride (PMSF) over about 30 min. Cell debris can be removed by centrifugation. Where the antibody is secreted into the medium, supernatants from such expression systems are generally first concentrated using a commercially available protein concentration filter, for example, an Amicon or Millipore Pellicon ultrafiltration unit. A protease inhibitor such as PMSF may be included in any of the foregoing steps to inhibit proteolysis and antibiotics may be  
10 included to prevent the growth of adventitious contaminants.

The antibody composition prepared from the cells can be purified using, for example, hydroxylapatite chromatography, gel electrophoresis, dialysis, and affinity chromatography, with affinity chromatography being the preferred purification technique. The suitability of protein A as an affinity ligand depends on the species and isotype of any immunoglobulin Fc domain that is present in the antibody.

15 Protein A can be used to purify antibodies that are based on human  $\gamma_1$ ,  $\gamma_2$ , or  $\gamma_4$  heavy chains (Lindmark *et al.*, *J. Immunol. Meth.* 62:1-13 (1983)). Protein G is recommended for all mouse isotypes and for human  $\gamma_3$  (Guss *et al.*, *EMBO J.* 5:1567-1575 (1986)). The matrix to which the affinity ligand is attached is most often agarose, but other matrices are available. Mechanically stable matrices such as controlled pore glass or poly(styrenedivinyl)benzene allow for faster flow rates and shorter processing times than can be achieved  
20 with agarose. Where the antibody comprises a C<sub>H</sub>3 domain, the Bakerbond ABX™resin (J. T. Baker, Phillipsburg, NJ) is useful for purification. Other techniques for protein purification such as fractionation on an ion-exchange column, ethanol precipitation, Reverse Phase HPLC, chromatography on silica, chromatography on heparin SEPHAROSE™ chromatography on an anion or cation exchange resin (such as a polyaspartic acid column), chromatofocusing, SDS-PAGE, and ammonium sulfate precipitation are also  
25 available depending on the antibody to be recovered.

Following any preliminary purification step(s), the mixture comprising the antibody of interest and contaminants may be subjected to low pH hydrophobic interaction chromatography using an elution buffer at a pH between about 2.5-4.5, preferably performed at low salt concentrations (*e.g.*, from about 0-0.25M salt).

30

### Antibody conjugates

The antibody may be conjugated to a cytotoxic agent such as a toxin or a radioactive isotope. In certain embodiments, the toxin is calicheamicin, a maytansinoid, a dolastatin, auristatin E and analogs or derivatives thereof, are preferable.

35 Preferred drugs/toxins include DNA damaging agents, inhibitors of microtubule polymerization or depolymerization and antimetabolites. Preferred classes of cytotoxic agents include, for example, the enzyme inhibitors such as dihydrofolate reductase inhibitors, and thymidylate synthase inhibitors, DNA intercalators, DNA cleavers, topoisomerase inhibitors, the anthracycline family of drugs, the vinca drugs, the mitomycins, the bleomycins, the cytotoxic nucleosides, the pteridine family of drugs, diynenes, the podophyllotoxins and differentiation inducers. Particularly useful members of those classes include, for example, methotrexate, methopterin, dichloromethotrexate, 5-fluorouracil, 6-mercaptopurine, cytosine arabinoside, melphalan, leurosine, leurosidine, actinomycin, daunorubicin, doxorubicin, N-(5,5-diacetoxypentyl)doxorubicin, morpholino-doxorubicin, 1-(2-choroethyl)-1,2-dimethanesulfonyl hydrazide, N<sup>8</sup>-acetyl spermidine, aminopterin methopterin, esperamicin, mitomycin C, mitomycin A, actinomycin,  
40

5 bleomycin, carminomycin, aminopterin, tallysomycin, podophyllotoxin and podophyllotoxin derivatives such as etoposide or etoposide phosphate, vinblastine, vincristine, vindesine, taxol, taxotere, retinoic acid, butyric acid, N<sup>8</sup>-acetyl spermidine, camptothecin, calicheamicin, bryostatins, cephalostatins, ansamitocin, actosin, maytansinoids such as DM-1, maytansine, maytansinol, N-desmethyl-4,5-desepoxymaytansinol, C-19-dechloromaytansinol, C-20-hydroxymaytansinol, C-20-demethoxymaytansinol, C-9-SH maytansinol, C-10 14-alkoxymethylmaytansinol, C-14-hydroxy or acetyloxymethylmaytansinol, C-15-hydroxy/acetyloxymaytansinol, C-15-methoxymaytansinol, C-18-N-demethylmaytansinol and 4,5-deoxymaytansinol, auristatins such as auristatin E, M, PHE and PE; dolostatins such as dolostatin A, dolostatin B, dolostatin C, dolostatin D, dolostatin E (20-epi and 11-epi), dolostatin G, dolostatin H, dolostatin I, dolostatin 1, dolostatin 2, dolostatin 3, dolostatin 4, dolostatin 5, dolostatin 6, dolostatin 7, dolostatin 8, dolostatin 9, dolostatin 10, deo-dolostatin 10, dolostatin 11, dolostatin 12, dolostatin 13, dolostatin 14, dolostatin 15, dolostatin 16, dolostatin 17, and dolostatin 18; cephalostatins such as 15 cephalostatin 1, cephalostatin 2, cephalostatin 3, cephalostatin 4, cephalostatin 5, cephalostatin 6, cephalostatin 7, 25'-epi-cephalostatin 7, 20-epi-cephalostatin 7, cephalostatin 8, cephalostatin 9, cephalostatin 10, cephalostatin 11, cephalostatin 12, cephalostatin 13, cephalostatin 14, cephalostatin 20 15, cephalostatin 16, cephalostatin 17, cephalostatin 18, and cephalostatin 19..

Maytansinoids are mitotoxic inhibitors which act by inhibiting tubulin polymerization. Maytansine was first isolated from the east African shrub *Maytenus serrata* (U.S. Patent No. 3,896,111). Subsequently, it was discovered that certain microbes also produce maytansinoids, such as maytansinol and C-3 maytansinol esters (U.S. Patent No. 4,151,042). Synthetic maytansinol and derivatives and analogues thereof are disclosed, for example, in U.S. Patent Nos. 4,137,230; 4,248,870; 4,256,746; 4,260,608; 4,265,814; 4,294,757; 4,307,016; 4,308,268; 4,308,269; 4,309,428; 4,313,946; 4,315,929; 4,317,821; 4,322,348; 4,331,598; 4,361,650; 4,364,866; 4,424,219; 4,450,254; 4,362,663; and 4,371,533, the disclosures of which are hereby expressly incorporated by reference.

Maytansine and maytansinoids have been conjugated to antibodies specifically binding to tumor cell antigens. Immunoconjugates containing maytansinoids and their therapeutic use are disclosed, for example, in U.S. Patent Nos. 5,208,020, 5,416,064 and European Patent EP 0 425 235 B1, the disclosures of which are hereby expressly incorporated by reference. Liu *et al.*, *Proc. Natl. Acad. Sci. USA* 93:8618-8623 (1996) described immunoconjugates comprising a maytansinoid designated DM1 linked to the monoclonal antibody C242 directed against human colorectal cancer. The conjugate was found to be highly cytotoxic towards cultured colon cancer cells, and showed antitumor activity in an *in vivo* tumor growth assay. Chari *et al.* *Cancer Research* 52:127-131 (1992) describe immunoconjugates in which a maytansinoid was conjugated via a disulfide linker to the murine antibody A7 binding to an antigen on human colon cancer cell lines, or to another murine monoclonal antibody TA.1 that binds the HER-2/neu oncogene.

There are many linking groups known in the art for making antibody-maytansinoid conjugates, including, for example, those disclosed in U.S. Patent No. 5,208,020 or EP Patent 0 425 235 B1, and Chari *et al.* *Cancer Research* 52: 127-131 (1992). The linking groups include disulfide groups, thioether groups, acid labile groups, photolabile groups, peptidase labile groups, or esterase labile groups, as disclosed in the above-identified patents, disulfide and thioether groups being preferred.

5       Conjugates of the antibody and maytansinoid may be made using a variety of bifunctional protein coupling agents such as N-succinimidyl-3-(2-pyridylidithio) propionate (SPDP), succinimidyl-4-(N-maleimidomethyl) cyclohexane-1-carboxylate, iminothiolane (IT), bifunctional derivatives of imidoesters (such as dimethyl adipimidate HCL), active esters (such as disuccinimidyl suberate), aldehydes (such as glutaraldehyde), bis-azido compounds (such as bis (p-azidobenzoyl) hexanediamine), bis-diazonium 10 derivatives (such as bis-(p-diazoniumbenzoyl)-ethylenediamine), diisocyanates (such as toluene 2,6-diisocyanate), and bis-active fluorine compounds (such as 1,5-difluoro-2,4-dinitrobenzene). Particularly preferred coupling agents include N-succinimidyl-3-(2-pyridylidithio) propionate (SPDP) (Carlsson *et al.*, *Biochem. J.* 173:723-737 [1978]) and N-succinimidyl-4-(2-pyridylthio)pentanoate (SPP) to provide for a disulfide linkage.

15      The linker may be attached to the maytansinoid molecule at various positions, depending on the type of the link. For example, an ester linkage may be formed by reaction with a hydroxyl group using conventional coupling techniques. The reaction may occur at the C-3 position having a hydroxyl group, the C-14 position modified with hyrdoxymethyl, the C-15 position modified with a hydroxyl group, and the C-20 position having a hydroxyl group. In a preferred embodiment, the linkage is formed at the C-3 position 20 of maytansinol or a maytansinol analogue.

#### *Calicheamicin*

Another immunoconjugate of interest comprises an CD20 binding antibody conjugated to one or more calicheamicin molecules. The calicheamicin family of antibiotics are capable of producing double-stranded DNA breaks at sub-picomolar concentrations. For the preparation of conjugates of the calicheamicin family, see U.S. patents 5,712,374, 5,714,586, 5,739,116, 5,767,285, 5,770,701, 5,770,710, 5,773,001, 5,877,296 (all to American Cyanamid Company). Structural analogues of calicheamicin which may be used include, but are not limited to,  $\gamma_1^I$ ,  $\alpha_2^I$ ,  $\alpha_3^I$ , N-acetyl- $\gamma_1^I$ , PSAG and  $\theta^I_1$  (Hinman *et al.* *Cancer Research* 53: 3336-3342 (1993), Lode *et al.* *Cancer Research* 58: 2925-2928 (1998) and the aforementioned 25 U.S. patents to American Cyanamid). Another anti-tumor drug that the antibody can be conjugated is QFA which is an antifolate. Both calicheamicin and QFA have intracellular sites of action and do not readily 30 cross the plasma membrane. Therefore, cellular uptake of these agents through antibody mediated internalization greatly enhances their cytotoxic effects.

#### *Radioactive isotopes*

For selective destruction of the tumor, the antibody may comprise a highly radioactive atom. A variety of radioactive isotopes are available for the production of radioconjugated anti-CD20 antibodies. Examples include At<sup>211</sup>, I<sup>131</sup>, I<sup>125</sup>, Y<sup>90</sup>, Re<sup>186</sup>, Re<sup>188</sup>, Sm<sup>153</sup>, Bi<sup>212</sup>, P<sup>32</sup>, Pb<sup>212</sup> and radioactive isotopes of Lu. When the conjugate is used for diagnosis, it may comprise a radioactive atom for scintigraphic studies, for 40 example tc<sup>99m</sup> or I<sup>123</sup>, or a spin label for nuclear magnetic resonance (NMR) imaging (also known as magnetic resonance imaging, mri), such as iodine-123 again, iodine-131, indium-111, fluorine-19, carbon-13, nitrogen-15, oxygen-17, gadolinium, manganese or iron.

The radio- or other labels may be incorporated in the conjugate in known ways. For example, the peptide may be biosynthesized or may be synthesized by chemical amino acid synthesis using suitable amino

5 acid precursors involving, for example, fluorine-19 in place of hydrogen. Labels such as  $\text{tc}^{99m}$  or  $\text{I}^{123}$ ,  $\text{Re}^{186}$ ,  $\text{Re}^{188}$  and  $\text{In}^{111}$  can be attached via a cysteine residue in the peptide. Yttrium-90 can be attached via a lysine residue. The IODOGEN method (Fraker et al (1978) *Biochem. Biophys. Res. Commun.* 80: 49-57 can be used to incorporate iodine-123. "Monoclonal Antibodies in Immunoscintigraphy" (Chatal,CRC Press 1989) describes other methods in detail.

10 Conjugates of the antibody and cytotoxic agent may be made using a variety of bifunctional protein coupling agents such as N-succinimidyl-3-(2-pyridylidithio) propionate (SPDP), succinimidyl-4-(N-maleimidomethyl) cyclohexane-1-carboxylate, iminothiolane (IT), bifunctional derivatives of imidoesters (such as dimethyl adipimidate HCL), active esters (such as disuccinimidyl suberate), aldehydes (such as glutaraldehyde), bis-azido compounds (such as bis (p-azidobenzoyl) hexanediamine), bis-diazonium 15 derivatives (such as bis-(p-diazoniumbenzoyl)-ethylenediamine), diisocyanates (such as tolyene 2,6-diisocyanate), and bis-active fluorine compounds (such as 1,5-difluoro-2,4-dinitrobenzene). For example, a ricin immunotoxin can be prepared as described in Vitetta *et al. Science* 238: 1098 (1987). Carbon-14-labeled 1-isothiocyanatobenzyl-3-methyldiethylene triaminepentaacetic acid (MX-DTPA) is an exemplary chelating agent for conjugation of radionucleotide to the antibody. See WO94/11026. The linker may be a 20 "cleavable linker" facilitating release of the cytotoxic drug in the cell. For example, an acid-labile linker, peptidase-sensitive linker, photolabile linker, dimethyl linker or disulfide-containing linker (Chari *et al. Cancer Research* 52: 127-131 (1992); U.S. Patent No. 5,208,020) may be used.

### Therapeutic Uses of the CD20 binding Antibodies

25 The CD20 binding antibodies of the invention are useful to treat a number of malignant and non-malignant diseases including autoimmune diseases and related conditions, and CD20 positive cancers including B cell lymphomas and leukemias. Stem cells (B-cell progenitors) in bone marrow lack the CD20 antigen, allowing healthy B-cells to regenerate after treatment and return to normal levels within several months.

30 Autoimmune diseases or autoimmune related conditions include arthritis (rheumatoid arthritis, juvenile rheumatoid arthritis, osteoarthritis, psoriatic arthritis), psoriasis, dermatitis including atopic dermatitis; chronic autoimmune urticaria, polymyositis/dermatomyositis, toxic epidermal necrolysis, systemic scleroderma and sclerosis, responses associated with inflammatory bowel disease (IBD) (Crohn's disease, ulcerative colitis), respiratory distress syndrome, adult respiratory distress syndrome (ARDS), meningitis, allergic rhinitis, encephalitis, uveitis, colitis, glomerulonephritis, allergic conditions, eczema, asthma, conditions involving infiltration of T cells and chronic inflammatory responses, atherosclerosis, 35 autoimmune myocarditis, leukocyte adhesion deficiency, systemic lupus erythematosus (SLE), lupus (including nephritis, non-renal, discoid, alopecia), juvenile onset diabetes, multiple sclerosis, allergic encephalomyelitis, immune responses associated with acute and delayed hypersensitivity mediated by cytokines and T-lymphocytes, tuberculosis, sarcoidosis, granulomatosis including Wegener's granulomatosis, agranulocytosis, vasculitis (including ANCA), aplastic anemia, Coombs positive anemia, Diamond Blackfan anemia, immune hemolytic anemia including autoimmune hemolytic anemia (AIHA), pernicious anemia, pure red cell aplasia (PRCA), Factor VIII deficiency, hemophilia A, autoimmune neutropenia, pancytopenia, leukopenia, diseases involving leukocyte diapedesis, CNS inflammatory

5 disorders, multiple organ injury syndrome, myasthenia gravis, antigen-antibody complex mediated diseases, anti-glomerular basement membrane disease, anti-phospholipid antibody syndrome, allergic neuritis, Bechet disease, Castleman's syndrome, Goodpasture's Syndrome, Lambert-Eaton Myasthenic Syndrome, Reynaud's syndrome, Sjorgen's syndrome, Stevens-Johnson syndrome, solid organ transplant rejection (including pretreatment for high panel reactive antibody titers, IgA deposit in tissues, etc), graft versus host disease  
10 (GVHD), pemphigoid bullous, pemphigus (all including vulgaris, foliatis), autoimmune polyendocrinopathies, Reiter's disease, stiff-man syndrome, giant cell arteritis, immune complex nephritis, IgA nephropathy, IgM polyneuropathies or IgM mediated neuropathy, idiopathic thrombocytopenic purpura (ITP), thrombotic thrombocytopenic purpura (TTP), autoimmune thrombocytopenia, autoimmune disease of the testis and ovary including autoimmune orchitis and oophoritis, primary hypothyroidism; autoimmune  
15 endocrine diseases including autoimmune thyroiditis, chronic thyroiditis (Hashimoto's Thyroiditis), subacute thyroiditis, idiopathic hypothyroidism, Addison's disease, Grave's disease, autoimmune polyglandular syndromes (or polyglandular endocrinopathy syndromes), Type I diabetes also referred to as insulin-dependent diabetes mellitus (IDDM) and Sheehan's syndrome; autoimmune hepatitis, Lymphoid interstitial pneumonitis (HIV), bronchiolitis obliterans (non-transplant) vs NSIP, Guillain-Barre' Syndrome, Large  
20 Vessel Vasculitis (including Polymyalgia Rheumatica and Giant Cell (Takayasu's) Arteritis), Medium Vessel Vasculitis (including Kawasaki's Disease and Polyarteritis Nodosa), ankylosing spondylitis, Berger's Disease (IgA nephropathy), Rapidly Progressive Glomerulonephritis, Primary biliary cirrhosis, Celiac sprue (gluten enteropathy), Cryoglobulinemia, ALS, coronary artery disease.

CD20 positive cancers are those comprising abnormal proliferation of cells that express CD20 on the cell surface. The CD20 positive B cell neoplasms include CD20-positive Hodgkin's disease including lymphocyte predominant Hodgkin's disease (LPHD); non-Hodgkin's lymphoma (NHL); follicular center cell (FCC) lymphomas; acute lymphocytic leukemia (ALL); chronic lymphocytic leukemia (CLL); Hairy cell leukemia. The non-Hodgkins lymphoma include low grade/follicular non-Hodgkin's lymphoma (NHL), small lymphocytic lymphoma (SLL), intermediate grade/follicular NHL, intermediate grade diffuse NHL,  
30 high grade immunoblastic NHL, high grade lymphoblastic NHL, high grade small non-cleaved cell NHL, bulky disease NHL, plasmacytoid lymphocytic lymphoma, mantle cell lymphoma, AIDS- related lymphoma and Waldenstrom's macroglobulinemia. Treatment of relapses of these cancers are also contemplated. LPHD is a type of Hodgkin's disease that tends to relapse frequently despite radiation or chemotherapy treatment and is characterized by CD20-positive malignant cells. CLL is one of four major types of  
35 leukemia. A cancer of mature B-cells called lymphocytes, CLL is manifested by progressive accumulation of cells in blood, bone marrow and lymphatic tissues.

In specific embodiments, the humanized CD20 binding antibodies and functional fragments thereof are used to treat non-Hodgkin's lymphoma (NHL), lymphocyte predominant Hodgkin's disease (LPHD), small lymphocytic lymphoma (SLL), chronic lymphocytic leukemia, rheumatoid arthritis and juvenile  
40 rheumatoid arthritis, systemic lupus erythematosus (SLE) including lupus nephritis, Wegener's disease, inflammatory bowel disease, idiopathic thrombocytopenic purpura (ITP), thrombotic thrombocytopenic purpura (TTP), autoimmune thrombocytopenia, multiple sclerosis, psoriasis, IgA nephropathy, IgM polyneuropathies, myasthenia gravis, vasculitis, diabetes mellitus, Reynaud's syndrome, Sjorgen's syndrome and glomerulonephritis.

5        The humanized CD20 binding antibodies or functional fragments thereof are useful as a single-agent treatment in, e.g., for relapsed or refractory low-grade or follicular, CD20-positive, B-cell NHL, or can be administered to patients in conjunction with other drugs in a multi drug regimen.

10      Indolent lymphoma is a slow-growing, incurable disease in which the average patient survives between six and 10 years following numerous periods of remission and relapse. In one embodiment, the humanized CD20 binding antibodies or functional fragments thereof are used to treat indolent NHL.

15      The parameters for assessing efficacy or success of treatment of the neoplasm will be known to the physician of skill in the appropriate disease. Generally, the physician of skill will look for reduction in the signs and symptoms of the specific disease. Parameters can include median time to disease progression, time in remission, stable disease.

20      The following references describe lymphomas and CLL, their diagnoses, treatment and standard medical procedures for measuring treatment efficacy.

25      The following references describe lymphomas and CLL, their diagnoses, treatment and standard medical procedures for measuring treatment efficacy. Canellos GP, Lister, TA, Sklar JL: *The Lymphomas*. W.B.Saunders Company, Philadelphia, 1998; van Besien K and Cabanillas, F: Clinical Manifestations, Staging and Treatment of Non-Hodgkin's Lymphoma, Chap. 70, pp 1293-1338, in: *Hematology , Basic Principles and Practice*, 3rd ed. Hoffman et al. (editors). Churchill Livingstone, Philadelphia, 2000; and Rai, K and Patel, D:Chronic Lymphocytic Leukemia, Chap. 72, pp 1350-1362, in: *Hematology , Basic Principles and Practice*, 3rd ed. Hoffman et al. (editors). Churchill Livingstone, Philadelphia, 2000.

30      The parameters for assessing efficacy or success of treatment of an autoimmune or autoimmune related disease will be known to the physician of skill in the appropriate disease. Generally, the physician of skill will look for reduction in the signs and symptoms of the specific disease. The following are by way of examples.

35      In one embodiment, the antibodies of the invention are useful to treat rheumatoid arthritis. RA is characterized by inflammation of multiple joints, cartilage loss and bone erosion that leads to joint destruction and ultimately reduced joint function. Additionally, since RA is a systemic disease, it can have effects in other tissues such as the lungs, eyes and bone marrow. Fewer than 50 percent of patients who have had RA for more than 10 years can continue to work or function normally on a day-to-day basis.

40      The antibodies can be used as first-line therapy in patients with early RA (i.e., methotrexate (MTX) naive) and as monotherapy, or in combination with, e.g., MTX or cyclophosphamide. Or, the antibodies can be used in treatment as second-line therapy for patients who were DMARD and/or MTX refractory, and as monotherapy or in combination with, e.g., MTX. The humanized CD20 binding antibodies are useful to prevent and control joint damage, delay structural damage, decrease pain associated with inflammation in RA, and generally reduce the signs and symptoms in moderate to severe RA. The RA patient can be treated with the humanized CD20 antibody prior to, after or together with treatment with other drugs used in treating RA (see combination therapy below). In one embodiment, patients who had previously failed disease-modifying antirheumatic drugs and/or had an inadequate response to methotrexate alone are treated with a humanized CD20 binding antibody of the invention. In one embodiment of this treatment, the patients are in a 17-day treatment regimen receiving humanized CD20 binding antibody alone (1g iv infusions on

5 days 1 and 15); CD20 binding antibody plus cyclophosphamide (750mg iv infusion days 3 and 17); or CD20 binding antibody plus methotrexate.

One method of evaluating treatment efficacy in RA is based on American College of Rheumatology (ACR) criteria, which measures the percentage of improvement in tender and swollen joints, among other things. The RA patient can be scored at for example, ACR 20 (20 percent improvement) compared with no 10 antibody treatment (e.g., baseline before treatment) or treatment with placebo. Other ways of evaluating the efficacy of antibody treatment include X-ray scoring such as the Sharp X-ray score used to score structural damage such as bone erosion and joint space narrowing. Patients can also be evaluated for the prevention of or improvement in disability based on Health Assessment Questionnaire [HAQ] score, AIMS score, SF-36 at time periods during or after treatment. The ACR 20 criteria may include 20% improvement in both tender 15 (painful) joint count and swollen joint count plus a 20% improvement in at least 3 of 5 additional measures:

- 20 1. patient's pain assessment by visual analog scale (VAS),
2. patient's global assessment of disease activity (VAS),
3. physician's global assessment of disease activity (VAS),
4. patient's self-assessed disability measured by the Health Assessment Questionnaire, and
5. acute phase reactants, CRP or ESR.

The ACR 50 and 70 are defined analogously. Preferably, the patient is administered an amount of a CD20 binding antibody of the invention effective to achieve at least a score of ACR 20, preferably at least ACR 30, 25 more preferably at least ACR50, even more preferably at least ACR70, most preferably at least ACR 75 and higher.

Psoriatic arthritis has unique and distinct radiographic features. For psoriatic arthritis, joint erosion and joint space narrowing can be evaluated by the Sharp score as well. The humanized CD20 binding antibodies of the invention can be used to prevent the joint damage as well as reduce disease signs and 30 symptoms of the disorder.

Yet another aspect of the invention is a method of treating Lupus or SLE by administering to the patient suffering from SLE, a therapeutically effective amount of a humanized CD20 binding antibody of the invention. SLEDAI scores provide a numerical quantitation of disease activity. The SLEDAI is a weighted index of 24 clinical and laboratory parameters known to correlate with disease activity, with a numerical 35 range of 0-103. see Bryan Gescuk & John Davis, "Novel therapeutic agent for systemic lupus erythematosus" in Current Opinion in Rheumatology 2002, 14:515-521. Antibodies to double-stranded DNA are believed to cause renal flares and other manifestations of lupus. Patients undergoing antibody treatment can be monitored for time to renal flare, which is defined as a significant, reproducible increase in serum creatinine, urine protein or blood in the urine. Alternatively or in addition, patients can be monitored for 40 levels of antinuclear antibodies and antibodies to double-stranded DNA. Treatments for SLE include high-dose corticosteroids and/or cyclophosphamide (HDCC).

Spondyloarthropathies are a group of disorders of the joints, including ankylosing spondylitis, psoriatic arthritis and Crohn's disease. Treatment success can be determined by validated patient and physician global assessment measuring tools.

45 Various medications are used to treat psoriasis; treatment differs directly in relation to disease severity. Patients with a more mild form of psoriasis typically utilize topical treatments, such as topical

5 steroids, anthralin, calcipotriene, clobetasol, and tazarotene, to manage the disease while patients with moderate and severe psoriasis are more likely to employ systemic (methotrexate, retinoids, cyclosporine, PUVA and UVB) therapies. Tars are also used. These therapies have a combination of safety concerns, time consuming regimens, or inconvenient processes of treatment. Furthermore, some require expensive equipment and dedicated space in the office setting. Systemic medications can produce serious side effects,  
10 including hypertension, hyperlipidemia, bone marrow suppression, liver disease, kidney disease and gastrointestinal upset. Also, the use of phototherapy can increase the incidence of skin cancers. In addition to the inconvenience and discomfort associated with the use of topical therapies, phototherapy and systemic treatments require cycling patients on and off therapy and monitoring lifetime exposure due to their side effects.

15 Treatment efficacy for psoriasis is assessed by monitoring changes in clinical signs and symptoms of the disease including Physician's Global Assessment (PGA) changes and Psoriasis Area and Severity Index (PASI) scores, Psoriasis Symptom Assessment (PSA), compared with the baseline condition. The patient can be measured periodically throughout treatment on the Visual analog scale used to indicate the degree of itching experienced at specific time points.

20 Patients may experience an infusion reaction or infusion-related symptoms with their first infusion of a therapeutic antibody. These symptoms vary in severity and generally are reversible with medical intervention. These symptoms include but are not limited to, flu-like fever, chills/rigors, nausea, urticaria, headache, bronchospasm, angioedema. It would be desirable for the disease treatment methods of the present invention to minimize infusion reactions. Thus, another aspect of the invention is a method of  
25 treating the diseases disclosed by administering a humanized CD20 binding antibody wherein the antibody has reduced or no complement dependent cytotoxicity and results in reduced infusion related symptoms as compared to treatment with Rituxan®. In one embodiment, the humanized CD20 binding antibody is 2H7.v116.

30 *Dosage*

Depending on the indication to be treated and factors relevant to the dosing that a physician of skill in the field would be familiar with, the antibodies of the invention will be administered at a dosage that is efficacious for the treatment of that indication while minimizing toxicity and side effects. For the treatment of a CD20 positive cancer or an autoimmune disease, the therapeutically effective dosage will be in the range of about 250mg/m<sup>2</sup> to about 400 mg/m<sup>2</sup> or 500 mg/m<sup>2</sup>, preferably about 250-375mg/m<sup>2</sup>. In one embodiment, the dosage range is 275-375 mg/m<sup>2</sup>. In one embodiment of the treatment of a CD20 positive B cell neoplasm, the antibody is administered at a range of 300-375 mg/m<sup>2</sup>. For the treatment of patients suffering from B-cell lymphoma such as non-Hodgkins lymphoma, in a specific embodiment, the anti-CD20 antibodies and humanized anti-CD20 antibodies of the invention will be administered to a human patient at a dosage of 10mg/kg or 375mg/m<sup>2</sup>. For treating NHL, one dosing regimen would be to administer one dose of the antibody composition a dosage of 10mg/kg in the first week of treatment, followed by a 2 week interval, then a second dose of the same amount of antibody is administered. Generally, NHL patients receive such treatment once during a year but upon recurrence of the lymphoma, such treatment can be repeated. In another dosing regimen, patients treated with low-grade NHL receive four weeks of a version of humanized

5 2H7, preferably v16 (375 mg/m<sup>2</sup> weekly) followed at week five by three additional courses of the antibody plus standard CHOP (cyclophosphamide, doxorubicin, vincristine and prednisone) or CVP (cyclophosphamide, vincristine, prednisone) chemotherapy, which was given every three weeks for three cycles.

For treating rheumatoid arthritis, in one embodiment, the dosage range for the humanized antibody 10 is 125mg/m<sup>2</sup> (equivalent to about 200mg/dose) to 600mg/m<sup>2</sup>, given in two doses, e.g., the first dose of 200mg is administered on day one followed by a second dose of 200mg on day 15. In different embodiments, the dosage is 250mg/dose, 275mg, 300mg, 325mg, 350mg, 375mg, 400mg, 425mg, 450mg, 475mg, 500mg, 525mg, 550mg, 575mg, 600mg.

In treating disease, the CD20 binding antibodies of the invention can be administered to the patient 15 chronically or intermittently, as determined by the physician of skill in the disease.

A patient administered a drug by intravenous infusion or subcutaneously may experience adverse events such as fever, chills, burning sensation, asthenia and headache. To alleviate or minimize such adverse events, the patient may receive an initial conditioning dose(s) of the antibody followed by a therapeutic dose. The conditioning dose(s) will be lower than the therapeutic dose to condition the patient to 20 tolerate higher dosages.

#### *Route of administration*

The CD20 binding antibodies are administered to a human patient in accord with known methods, such as by intravenous administration, e.g., as a bolus or by continuous infusion over a period of time, by 25 subcutaneous, intramuscular, intraperitoneal, intracerebrospinal, intra-articular, intrasynovial, intrathecal, or inhalation routes, generally by intravenous or subcutaneous administration.

In one embodiment, the humanized 2H7 antibody is administered by intravenous infusion with 0.9% sodium chloride solution as an infusion vehicle.

#### *Combination Therapy*

In treating the B cell neoplasms described above, the patient can be treated with the CD20 binding antibodies of the present invention in conjunction with one or more therapeutic agents such as a chemotherapeutic agent in a multidrug regimen. The CD20 binding antibody can be administered concurrently, sequentially, or alternating with the chemotherapeutic agent, or after non-responsiveness with 35 other therapy. Standard chemotherapy for lymphoma treatment may include cyclophosphamide, cytarabine, melphalan and mitoxantrone plus melphalan. CHOP is one of the most common chemotherapy regimens for treating Non-Hodgkin's lymphoma. The following are the drugs used in the CHOP regimen: cyclophosphamide (brand names cytoxin, neosar); adriamycin (doxorubicin / hydroxydoxorubicin); vincristine (Oncovin); and prednisolone (sometimes called Deltasone or Orasone). In particular 40 embodiments, the CD20 binding antibody is administered to a patient in need thereof in combination with one or more of the following chemotherapeutic agents of doxorubicin, cyclophosphamide, vincristine and prednisolone. In a specific embodiment, a patient suffering from a lymphoma (such as a non-Hodgkin's lymphoma) is treated with an anti-CD20 antibody of the present invention in conjunction with CHOP (cyclophosphamide, doxorubicin, vincristine and prednisone) therapy. In another embodiment, the cancer

5 patient can be treated with a humanized CD20 binding antibody of the invention in combination with CVP (cyclophosphamide, vincristine, and prednisone) chemotherapy. In a specific embodiment, the patient suffering from CD20-positive NHL is treated with humanized 2H7.v16 in conjunction with CVP. In a specific embodiment of the treatment of CLL, the CD20 binding antibody is administered in conjunction with chemotherapy with one or both of fludarabine and cytoxan.

10 In treating the autoimmune diseases or autoimmune related conditions described above, the patient can be treated with the CD20 binding antibodies of the present invention in conjunction with a second therapeutic agent, such as an immunosuppressive agent, such as in a multi drug regimen. The CD20 binding antibody can be administered concurrently, sequentially or alternating with the immunosuppressive agent or upon non-responsiveness with other therapy. The immunosuppressive agent can be administered at the 15 same or lesser dosages than as set forth in the art. The preferred adjunct immunosuppressive agent will depend on many factors, including the type of disorder being treated as well as the patient's history.

"Immunosuppressive agent" as used herein for adjunct therapy refers to substances that act to suppress or mask the immune system of a patient. Such agents would include substances that suppress cytokine production, down regulate or suppress self-antigen expression, or mask the MHC antigens.

20 Examples of such agents include steroids such as glucocorticosteroids, e.g., prednisone, methylprednisolone, and dexamethasone; 2-amino-6-aryl-5-substituted pyrimidines (see U.S. Pat. No. 4,665,077), azathioprine (or cyclophosphamide, if there is an adverse reaction to azathioprine); bromocryptine; glutaraldehyde (which masks the MHC antigens, as described in U.S. Pat. No. 4,120,649); anti-idiotypic antibodies for MHC antigens and MHC fragments; cyclosporin A; cytokine or cytokine receptor antagonists including anti- 25 interferon- $\gamma$ , - $\beta$ , or - $\alpha$  antibodies; anti-tumor necrosis factor- $\alpha$  antibodies; anti-tumor necrosis factor- $\beta$  antibodies; anti-interleukin-2 antibodies and anti-IL-2 receptor antibodies; anti-L3T4 antibodies; heterologous anti-lymphocyte globulin; pan-T antibodies, preferably anti-CD3 or anti-CD4/CD4a antibodies; soluble peptide containing a LFA-3 binding domain (WO 90/08187 published 7/26/90); streptokinase; TGF- $\beta$ ; streptodornase; RNA or DNA from the host; FK506; RS-61443; deoxyspergualin; 30 rapamycin; T-cell receptor (U.S. Pat. No. 5,114,721); T-cell receptor fragments (Offner *et al.*, *Science* 251:430-432 (1991); WO 90/11294; and WO 91/01133); and T cell receptor antibodies (EP 340,109) such as T10B9.

For the treatment of rheumatoid arthritis, the patient can be treated with a CD20 antibody of the invention in conjunction with any one or more of the following drugs: DMARDs (disease-modifying anti- 35 rheumatic drugs (e.g., methotrexate), NSAII or NSAID (non-steroidal anti-inflammatory drugs), HUMIRA™ (adalimumab; Abbott Laboratories), ARAVA® (leflunomide), REMICADE® (infliximab; Centocor Inc., of Malvern, Pa), ENBREL (etanercept; Immunex, WA), COX-2 inhibitors. DMARDs commonly used in RA are hydroxychloroquine, sulfasalazine, methotrexate, leflunomide, etanercept, infliximab, azathioprine, D-penicillamine, Gold (oral), Gold (intramuscular), minocycline, cyclosporine, 40 Staphylococcal protein A immunoabsorption. Adalimumab is a human monoclonal antibody that binds to TNF $\alpha$ . Infliximab is a chimeric monoclonal antibody that binds to TNF $\alpha$ . Etanercept is an "immunoadhesin" fusion protein consisting of the extracellular ligand binding portion of the human 75 kD (p75) tumor necrosis factor receptor (TNFR) linked to the Fc portion of a human IgG1. For conventional treatment of RA, see, e.g., "Guidelines for the management of rheumatoid arthritis" *Arthritis & Rheumatism*

5 46(2): 328-346 (February, 2002). In a specific embodiment, the RA patient is treated with a CD20 antibody of the invention in conjunction with methotrexate (MTX). An exemplary dosage of MTX is about 7.5-25 mg/kg/wk. MTX can be administered orally and subcutaneously.

For the treatment of ankylosing spondylitis, psoriatic arthritis and Crohn's disease, the patient can be treated with a CD20 binding antibody of the invention in conjunction with, for example, Remicade® (10 infliximab; from Centocor Inc., of Malvern, Pa.), ENBREL (etanercept; Immunex, WA).

Treatments for SLE include high-dose corticosteroids and/or cyclophosphamide (HDCC).

For the treatment of psoriasis, patients can be administered a CD20 binding antibody in conjunction with topical treatments, such as topical steroids, anthralin, calcipotriene, clobetasol, and tazarotene, or with methotrexate, retinoids, cyclosporine, PUVA and UVB therapies. In one embodiment, the psoriasis patient 15 is treated with the CD20 binding antibody sequentially or concurrently with cyclosporine.

### Pharmaceutical Formulations

Therapeutic formulations of the CD20-binding antibodies used in accordance with the present invention are prepared for storage by mixing an antibody having the desired degree of purity with optional 20 pharmaceutically acceptable carriers, excipients or stabilizers (*Remington's Pharmaceutical Sciences* 16th edition, Osol, A. Ed. (1980)), in the form of lyophilized formulations or aqueous solutions. Acceptable carriers, excipients, or stabilizers are nontoxic to recipients at the dosages and concentrations employed, and include buffers such as phosphate, citrate, and other organic acids; antioxidants including ascorbic acid and methionine; preservatives (such as octadecyldimethylbenzyl ammonium chloride; hexamethonium chloride; 25 benzalkonium chloride, benzethonium chloride; phenol, butyl or benzyl alcohol; alkyl parabens such as methyl or propyl paraben; catechol; resorcinol; cyclohexanol; 3-pentanol; and m-cresol); low molecular weight (less than about 10 residues) polypeptides; proteins, such as serum albumin, gelatin, or immunoglobulins; hydrophilic polymers such as olyvinylpyrrolidone; amino acids such as glycine, glutamine, asparagine, histidine, arginine, or lysine; monosaccharides, disaccharides, and other 30 carbohydrates including glucose, mannose, or dextrans; chelating agents such as EDTA; sugars such as sucrose, mannitol, trehalose or sorbitol; salt-forming counter-ions such as sodium; metal complexes (e.g. Zn-protein complexes); and/or non-ionic surfactants such as TWEEN™, PLURONIC™ or polyethylene glycol (PEG).

Exemplary anti-CD20 antibody formulations are described in WO98/56418, expressly incorporated 35 herein by reference. Another formulation is a liquid multidose formulation comprising the anti-CD20 antibody at 40 mg/mL, 25 mM acetate, 150 mM trehalose, 0.9% benzyl alcohol, 0.02% polysorbate 20 at pH 5.0 that has a minimum shelf life of two years storage at 2-8°C. Another anti-CD20 formulation of interest comprises 10mg/mL antibody in 9.0 mg/mL sodium chloride, 7.35 mg/mL sodium citrate dihydrate, 0.7mg/mL polysorbate 80, and Sterile Water for Injection, pH 6.5. Yet another aqueous pharmaceutical 40 formulation comprises 10-30 mM sodium acetate from about pH 4.8 to about pH 5.5, preferably at pH5.5, polysorbate as a surfactant in a an amount of about 0.01-0.1% v/v, trehalose at an amount of about 2-10% w/v, and benzyl alcohol as a preservative (U.S. 6,171,586). Lyophilized formulations adapted for subcutaneous administration are described in WO97/04801. Such lyophilized formulations may be

5 reconstituted with a suitable diluent to a high protein concentration and the reconstituted formulation may be administered subcutaneously to the mammal to be treated herein.

One formulation for the humanized 2H7 variants is antibody at 12-14 mg/mL in 10 mM histidine, 6% sucrose, 0.02% polysorbate 20, pH 5.8.

10 In a specific embodiment, 2H7 variants and in particular 2H7.v16 is formulated at 20mg/mL antibody in 10mM histidine sulfate, 60mg/ml sucrose., 0.2 mg/ml polysorbate 20, and Sterile Water for Injection, at pH5.8.

15 The formulation herein may also contain more than one active compound as necessary for the particular indication being treated, preferably those with complementary activities that do not adversely affect each other. For example, it may be desirable to further provide a cytotoxic agent, chemotherapeutic agent, cytokine or immunosuppressive agent (*e.g.* one which acts on T cells, such as cyclosporin or an antibody that binds T cells, *e.g.* one which binds LFA-1). The effective amount of such other agents depends on the amount of antibody present in the formulation, the type of disease or disorder or treatment, and other factors discussed above. These are generally used in the same dosages and with administration routes as described herein or about from 1 to 99% of the heretofore employed dosages.

20 The active ingredients may also be entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization, for example, hydroxymethylcellulose or gelatin-microcapsules and poly-(methylmethacrylate) microcapsules, respectively, in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nano-particles and nanocapsules) or in macroemulsions. Such techniques are disclosed in *Remington's Pharmaceutical Sciences* 16th edition, Osol, 25 A. Ed. (1980).

Sustained-release preparations may be prepared. Suitable examples of sustained-release preparations include semi-permeable matrices of solid hydrophobic polymers containing the antagonist, which matrices are in the form of shaped articles, *e.g.* films, or microcapsules. Examples of sustained-release matrices include polyesters, hydrogels (for example, poly(2-hydroxyethyl-methacrylate), or 30 poly(vinylalcohol)), polylactides (U.S. Pat. No. 3,773,919), copolymers of L-glutamic acid and ethyl-L-glutamate, non-degradable ethylene-vinyl acetate, degradable lactic acid-glycolic acid copolymers such as the LUPRON DEPOT™ (injectable microspheres composed of lactic acid-glycolic acid copolymer and leuprolide acetate), and poly-D-(-)-3-hydroxybutyric acid.

35 The formulations to be used for *in vivo* administration must be sterile. This is readily accomplished by filtration through sterile filtration membranes.

#### Articles of Manufacture and Kits

Another embodiment of the invention is an article of manufacture containing materials useful for the treatment of autoimmune diseases and related conditions and CD20 positive cancers such as non-Hodgkin's lymphoma. The article of manufacture comprises a container and a label or package insert on or 40 associated with the container. Suitable containers include, for example, bottles, vials, syringes, etc. The containers may be formed from a variety of materials such as glass or plastic. The container holds a composition which is effective for treating the condition and may have a sterile access port (for example the container may be an intravenous solution bag or a vial having a stopper pierceable by a hypodermic injection

5 needle). At least one active agent in the composition is a CD20 binding antibody of the invention. The label or package insert indicates that the composition is used for treating the particular condition. The label or package insert will further comprise instructions for administering the antibody composition to the patient. Package insert refers to instructions customarily included in commercial packages of therapeutic products, that contain information about the indications, usage, dosage, administration, contraindications and/or  
10 warnings concerning the use of such therapeutic products. In one embodiment, the package insert indicates that the composition is used for treating non-Hodgkins' lymphoma.

15 Additionally, the article of manufacture may further comprise a second container comprising a pharmaceutically-acceptable buffer, such as bacteriostatic water for injection (BWFI), phosphate-buffered saline, Ringer's solution and dextrose solution. It may further include other materials desirable from a commercial and user standpoint, including other buffers, diluents, filters, needles, and syringes.

Kits are also provided that are useful for various purposes, e.g., for B-cell killing assays, as a positive control for apoptosis assays, for purification or immunoprecipitation of CD20 from cells. For isolation and purification of CD20, the kit can contain an anti-CD20 antibody coupled to beads (e.g., sepharose beads). Kits can be provided which contain the antibodies for detection and quantitation of CD20  
20 *in vitro*, e.g. in an ELISA or a Western blot. As with the article of manufacture, the kit comprises a container and a label or package insert on or associated with the container. The container holds a composition comprising at least one anti-CD20 antibody of the invention. Additional containers may be included that contain, e.g., diluents and buffers, control antibodies. The label or package insert may provide a description of the composition as well as instructions for the intended *in vitro* or diagnostic use.  
25

### Cynomolgus monkey CD20

The invention also provides an isolated nucleic acid comprising the nucleotide sequence of SEQ ID NO.: \_ of the Cynomolgus monkey CD20 as shown in FIG. 19. In one embodiment, the nucleic acid is a cDNA. In one embodiment, the nucleic acid encoding the monkey CD20 is in an expression vector for expression in a host cell. The nucleotide sequence of SEQ ID NO.: \_ in the expression vector is operably linked to an expression control sequence such as a promoter or promoter and enhancer. The expression control sequence can be the native sequence normally associated with the Cynomolgus CD20 gene, or heterologous to the gene. Also provided is an isolated polypeptide comprising the amino acid sequence [SEQ ID NO. \_ ; FIG. 19 & 20] of the Cynomolgus monkey CD20, as well as host cells containing the  
30 Cynomolgus CD20 nucleic acid. In one aspect the host cells are eukaryotic cells, e.g., CHO cells. Fusion proteins comprising the Cynomolgus CD20 amino acid sequence or fragments of the sequence are also contemplated.  
35

### Experimental Examples

40

#### Example 1

##### **Humanization of 2H7 anti-CD20 murine monoclonal antibody**

Humanization of the murine anti-human CD20 antibody, 2H7 (also referred to herein as m2H7, m for murine), was carried out in a series of site-directed mutagenesis steps. The murine 2H7 antibody  
45 variable region sequences and the chimeric 2H7 with the mouse V and human C have been described, see,

5 e.g., U.S. patents 5,846,818 and 6,204,023. The CDR residues of 2H7 were identified by comparing the amino acid sequence of the murine 2H7 variable domains (disclosed in U.S. 5,846,818) with the sequences of known antibodies (Kabat et al., Sequences of proteins of immunological interest, Ed. 5. Public Health Service, National Institutes of Health, Bethesda, MD (1991)). The CDR regions for the light and heavy chains were defined based on sequence hypervariability (Kabat et al., *supra*) and are shown in Fig. 1A and  
10 Fig. 1B, respectively. Using synthetic oligonucleotides (Table 1), site-directed mutagenesis (Kunkel, *Proc. Natl. Acad. Sci.* 82:488-492 (1985)) was used to introduce all six of the murine 2H7 CDR regions into a complete human Fab framework corresponding to a consensus sequence V<sub>κ</sub>I,V<sub>H</sub>III (V<sub>L</sub> kappa subgroup I, V<sub>H</sub> subgroup III) contained on plasmid pVX4 (Fig. 2).

The phagemid pVX4 (Fig. 2) was used for mutagenesis as well as for expression of F(ab)s in E.  
15 coli. Based on the phagemid pb0720, a derivative of pB0475 (Cunningham et al., *Science* 243: 1330-1336 (1989)), pVX4 contains a DNA fragment encoding a humanized consensus κ-subgroup I light chain (V<sub>L</sub>KI-C<sub>L</sub>) and a humanized consensus subgroup III heavy chain (V<sub>H</sub>III-C<sub>H</sub>1) anti-IFN-α (interferon α) antibody. pVX4 also has an alkaline phosphatase promotor and Shine-Dalgamo sequence both derived from another previously described pUC119-based plasmid, pAK2 (Carter et al., *Proc. Natl. Acad. Sci. USA* 89: 4285  
20 (1992)). A unique Spel restriction site was introduced between the DNA encoding for the F(ab) light and heavy chains. The first 23 amino acids in both anti-IFN-α heavy and light chains are the SII secretion signal sequence (Chang et al., *Gene* 55: 189-196 (1987)).

To construct the CDR-swap version of 2H7 (2H7.v2), site-directed mutagenesis was performed on a deoxyuridine-containing template of pVX4; all six CDRs of anti-IFN-α were changed to the murine 2H7 CDRs. The resulting molecule is referred to as humanized 2H7 version 2 (2H7.v2), or the “CDR-swap version” of 2H7; it has the m2H7 CDR residues with the consensus human FR residues shown in Figures 1A and 1B. Humanized 2H7.v2 was used for further humanization.

Table 1 shows the oligonucleotide sequence used to create each of the murine 2H7 (m2H7) CDRs in the H and L chain. For example, the CDR-H1 oligonucleotide was used to recreate the m2H7 H chain  
30 CDR1. CDR-H1, CDR-H2 and CDR-H3 refers to the H chain CDR1, CDR2 and CDR3, respectively; similarly, CDR-L1, CDR-L2 and CDR-L3 refers to each of the L chain CDRs. The substitutions in CDR-H2 were done in two steps with two oligonucleotides, CDR-H2A and CDR-H2B.

**Table 1.** Oligonucleotide sequences used for construction of the CDR-swap of murine 2H7 CDRs into a human framework in pVX4. Residues changed by each oligonucleotide are underlined.

Substitution	Oligonucleotide sequence
CDR-H1	C TAC ACC TTC ACG <u>AGC</u> TAT <u>AAC</u> <u>ATG</u> CAC TGG GTC CG (SEQ ID NO. )
CDR-H2A	G ATT AAT CCT GAC <u>AAC</u> <u>GGC</u> <u>GAC</u> ACG <u>AGC</u> TAT AAC CAG <u>AAG</u> TTC AAG GGC CG (SEQ ID NO. )
CDR-H2B	GAA TGG GTT GCA <u>GCG</u> ATC <u>TAT</u> CCT <u>GGC</u> AAC GGC GAC AC (SEQ ID NO. )
CDR-H3	AT TAT TGT GCT CGA GTG GTC <u>TAC</u> TAT AGC <u>AAC</u> <u>AGC</u> <u>TAC</u> TGG <u>TAC</u> <u>TTC</u> GAC GTC TGG GGT CAA GGA (SEQ ID NO. )
CDR-L1	C TGC ACA GCC AGC <u>TCT</u> TCT <u>GTC</u> AGC TAT ATG CAT TG (SEQ ID NO. )
CDR-L2	AA CTA CTG ATT TAC <u>GCT</u> <u>CCA</u> <u>TCG</u> AAC CTC <u>GCG</u> TCT GGA GTC C (SEQ ID NO. )
CDR-L3	TAT TAC TGT CAA CAG <u>TGG</u> <u>AGC</u> <u>TTC</u> <u>AAT</u> CCG <u>CCC</u> ACA TTT GGA

	CAG (SEQ ID NO. )
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5

For comparison with humanized constructs, a plasmid expressing a chimeric 2H7 Fab (containing murine V<sub>L</sub> and V<sub>H</sub> domains, and human C<sub>L</sub> and CH<sub>1</sub> domains) was constructed by site-directed mutagenesis (Kunkel, *supra*) using synthetic oligonucleotides to introduce the murine framework residues into 2H7.v2. The sequence of the resulting plasmid construct for expression of the chimeric Fab known as 2H7.v6.8, is shown in Fig. 3. Each encoded chain of the Fab has a 23 amino acid SfII secretion signal sequence as described for pVX4 (Fig. 2) above.

10 Based on a sequence comparison of the murine 2H7 framework residues with the human V<sub>K</sub>I, V<sub>H</sub>III consensus framework (Figures 1A and 1B) and previously humanized antibodies (Carter et al., *Proc. Natl. Acad. Sci. USA* 89:4285-4289 (1992)), several framework mutations were introduced into the 2H7.v2 Fab 15 construct by site-directed mutagenesis. These mutations result in a change of certain human consensus framework residues to those found in the murine 2H7 framework, at sites that might affect CDR conformations or antigen contacts. Version 3 contained V<sub>H</sub>(R71V, N73K), version 4 contained V<sub>H</sub>(R71V), version 5 contained V<sub>H</sub>(R71V, N73K) and V<sub>L</sub>(L46P), and version 6 contained V<sub>H</sub>(R71V, N73K) and V<sub>L</sub>(L46P, L47W).

20 Humanized and chimeric Fab versions of m2H7 antibody were expressed in E. coli and purified as follows. Plasmids were transformed into E. coli strain XL-1 Blue (Stratagene, San Diego, CA) for preparation of double-and single-stranded DNA. For each variant, both light and heavy chains were completely sequenced using the dideoxynucleotide method (Sequenase, U.S. Biochemical Corp.). Plasmids were transformed into E. coli strain 16C9, a derivative of MM294, plated onto LB plates containing 5 µg/ml 25 carbenicillin, and a single colony selected for protein expression. The single colony was grown in 5 ml LB-100 µg/ml carbenicillin for 5-8 h at 37° C. The 5 ml culture was added to 500 ml AP5-100 µg/ml carbenicillin and allowed to grow for 16 h in a 4 L baffled shake flask at 37°C. AP5 media consists of: 1.5g glucose, 11.0 Hycase SF, 0.6g yeast extract (certified), 0.19g anhydrous MgSO<sub>4</sub>, 1.07g NH<sub>4</sub>Cl, 3.73g KCl, 1.2g NaCl, 120 ml 1 M triethanolamine, pH 7.4, to 1 L water and then sterile filtered through 0.1 µm 30 Sealkeen filter.

Cells were harvested by centrifugation in a 1 L centrifuge bottle (Nalgene) at 3000xg and the supernatant removed. After freezing for 1 h, the pellet was resuspended in 25 ml cold 10 mM MES-10 mM EDTA, pH 5.0 (buffer A). 250 µl of 0.1M PMSF (Sigma) was added to inhibit proteolysis and 3.5 ml of stock 10 mg/ml hen egg white lysozyme (Sigma) was added to aid lysis of the bacterial cell wall. After 35 gentle shaking on ice for 1 h, the sample was centrifuged at 40,000xg for 15 min. The supernatant was brought to 50 ml with buffer A and loaded onto a 2 ml DEAE column equilibrated with buffer A. The flow-through was then applied to a protein G-Sepharose CL-4B (Pharmacia) column (0.5 ml bed volume) equilibrated with buffer A. The column was washed with 10 ml buffer A and eluted with 3 ml 0.3 M glycine, pH 3.0, into 1.25 ml 1 M Tris, pH 8.0. The F(ab) was then buffer exchanged into PBS using a 40 Centricon-30 (Amicon) and concentrated to a final volume of 0.5 ml. SDS-PAGE gels of all F(ab)s were run to ascertain purity and the molecular weight of each variant was verified by electrospray mass spectrometry.

5 In cell-based ELISA binding assays (described below), the binding of Fabs, including chimeric 2H7 Fab, to CD20 was difficult to detect. Therefore, the 2H7 Fab versions were reformatted as full-length IgG1 antibodies for assays and further mutagenesis.

Plasmids for expression of full-length IgG's were constructed by subcloning the V<sub>L</sub> and V<sub>H</sub> domains of chimeric 2H7 (v6.8) Fab as well as humanized Fab versions 2 to 6 into previously described 10 pRK vectors for mammalian cell expression (Gorman et al.; *DNA Prot. Eng. Tech.* 2:3-10 (1990)). Briefly, each Fab construct was digested with *EcoRV* and *BspI* to excise a V<sub>L</sub> fragment, which was cloned into the *EcoRV/BspI* sites of plasmid pDR1 (Fig. 4) for expression of the complete light chain (V<sub>L</sub>-C<sub>L</sub> domains). Additionally, each Fab construct was digested with *PvuII* and *ApaI* to excise a V<sub>H</sub> fragment, which was 15 cloned into the *PvuII/ApaI* sites of plasmid pDR2 (Fig. 5) for expression of the complete heavy chain (V<sub>H</sub>-CH<sub>1</sub>-hinge-CH<sub>2</sub>-CH<sub>3</sub> domains). For each IgG variant, transient transfections were performed by cotransfected a light-chain expressing plasmid and a heavy-chain expressing plasmid into an adenovirus-transformed human embryonic kidney cell line, 293 (Graham et al., *J. Gen. Virol.*, 36:59-74, (1977)). Briefly, 293 cells were split on the day prior to transfection, and plated in serum-containing medium. On the following day, double-stranded DNA prepared as a calcium phosphate precipitate was added, followed by 20 pAdVAntage™ DNA (Promega, Madison, WI), and cells were incubated overnight at 37°C. Cells were cultured in serum-free medium and harvested after 4 days. Antibodies were purified from culture supernatants using protein A-Sepharose CL-4B, then buffer exchanged into 10 mM sodium succinate, 140 mM NaCl, pH 6.0, and concentrated using a Centricon-10 (Amicon). Protein concentrations were determined by quantitative amino acid analysis.

25 To measure relative binding affinities to the CD20 antigen, a cell-based ELISA assay was developed. Human B-lymphoblastoid WIL2-S cells (ATCC CRL 8885, American Type Culture Collection, Rockville, MD) were grown in RPMI 1640 supplemented with 2 mM L-glutamine, 20 mM HEPES, pH 7.2 and 10% heat-inactivated fetal bovine serum in a humidified 5% CO<sub>2</sub> incubator. The cells were washed with PBS containing 1% FBS (assay buffer) and seeded at 250-300,000 cell/well in 96-well round bottom plates 30 (Nunc, Roskilde, Denmark). Two-fold serially diluted standard (15.6-1000 ng/ml of 2H7 v6.8 chimeric IgG) and threefold serially diluted samples (2.7-2000 ng/ml) in assay buffer were added to the plates. The plates were buried in ice and incubated for 45 min. To remove the unbound antibody, 0.1 mL assay buffer were added to the wells. Plates were centrifuged and supernatants were removed. Cells were washed two more times with 0.2 mL assay buffer. Antibody bound to the plates was detected by adding peroxidase conjugated 35 goat anti-human Fc antibody (Jackson ImmunoResearch, West Grove, PA) to the plates. After a 45 min incubation, cells were washed as described before. TMB substrate (3,3',5,5'-tetramethyl benzidine; Kirkegaard & Perry Laboratories, Gaithersburg, MD) was added to the plates. The reaction was stopped by adding 1 M phosphoric acid. Titration curves were fit with a four-parameter nonlinear regression curve-fitting program (KaleidaGraph, Synergy software, Reading, PA). The absorbance at the midpoint of the 40 titration curve (mid-OD) and its corresponding concentration of the standard were determined. Then the concentration of each variant at this mid-OD was determined, and the concentration of the standard was divided by that of each variant. Hence the values are a ratio of the binding of each variant relative to the

5 standard. Standard deviations in relative affinity (equivalent concentration) were generally +/- 10% between experiments.

As shown in Table 2, binding of the CDR-swap variant (v.2) was extremely reduced compared to chimeric 2H7 (v.6.8). However, versions 3 to 6 showed improved binding. To determine the minimum number of mutations that might be required to restore binding affinity to that of chimeric 2H7, additional 10 mutations and combinations of mutations were constructed by site-direct mutagenesis to produce variants 7 to 17 as indicated in Table 3. In particular, these included V<sub>H</sub> mutations A49G, F67A, I69L, N73K, and L78A; and V<sub>L</sub> mutations M4L, M33I, and F71Y. Versions 16 and 17 showed the best relative binding affinities, within 2-fold of that of the chimeric version, with no significant difference (s.d. = +/- 10%) between the two. To minimize the number of mutations, version 16, having only 4 mutations of human 15 framework residues to murine framework residues (Table 3), was therefore chosen as the humanized form for additional characterization.

20 **Table 2.** Relative binding affinity of humanized 2H7 IgG variants to CD20 compared to chimeric 2H7 using cell-based ELISA. The relative binding is expressed as the concentration of the chimeric 2H7 over the concentration of the variant required for equivalent binding; hence a ratio <1 indicates weaker affinity for the variant. Standard deviation in relative affinity determination averaged +/- 10%. Framework substitutions in the variable domains are relative to the CDR-swap version according to the numbering system of Kabat (Kabat et al., *supra*).

2H7 version	Heavy chain (V <sub>H</sub> ) substitutions	Light Chain (V <sub>L</sub> ) substitutions	Relative binding
6.8	(Chimera)	(Chimera)	-1-
2	(CDR swap)	(CDR swap)	0.01
3	R71V, N73K	(CDR swap)	0.21
4	R71V	(CDR swap)	0.21
5	R71V, N73K	L46P	0.50
6	R71V, N73K	L46P, L47W	0.58
7	R71V	L46P	0.33
8	R71V, L78A	L46P	0.19
9	R71V, F67A	L46P	0.07
10	R71V, F67A, I69L	L46P	0.12
11	R71V, F67A, L78A	L46P	0.19
12	R71V	L46P, M4L	0.32
13	R71V	L46P, M33I	0.31
14	R71V	L46P, F71Y	0.25
15	R71V	L46P, M4L, M33I	0.26
16	R71V, N73K, A49G	L46P	0.65
17	R71V, N73K, A49G	L46P, L47W	0.67

5      **Table 3** Oligonucleotide sequences used for construction of mutations V<sub>H</sub>(A49G, R71V, N73K) and  
 VL(L46P) in humanized 2H7 version 16 (2H7.v16). Underlined codons encode the indicated amino acid  
 substitutions. For V<sub>H</sub> (R71V, N73K) and V<sub>L</sub> (L46P), the oligos are shown as the sense strand since these  
 were used for mutagenesis on the Fab template, while for V<sub>H</sub> (A49G), the oligo is shown as the anti-sense  
 strand, since this was used with the pRK (IgG heavy chain) template. The protein sequence of version 16 is  
 10     shown in Fig. 6 and Fig. 7.

Substitution	Oligonucleotide sequence
V <sub>H</sub> (R71V, N73K)	GT TTC ACT ATA AGT <u>GTC</u> GAC <u>AAG</u> TCC AAA AAC ACA TT (SEQ ID NO. )
V <sub>H</sub> (A49G)	GCCAGGATAGATGGCGCCAACCCATTCCAGGCC (SEQ ID NO. )
V <sub>L</sub> (L46P)	AAGCTCCGAAACCACTGATTACGCT (SEQ ID NO. )

**Example 2**  
**Antigen-binding determinants (paratope) of 2H7**

Alanine substitutions (Cunningham & Wells, *Science* 244: 1081-1085 (1989) were made in  
 15     2H7.v16 or 2H7.v17 in order to test the contributions of individual side chains of the antibody in binding to  
 CD20. IgG variants were expressed in 293 cells from pDR1 and pDR2 vectors, purified, and assayed for  
 relative binding affinity as described above. Several alanine substitutions resulted in significant decreases in  
 relative binding to CD20 on WIL-2S cells (Table 4).

20     Table 4. Effects of alanine substitutions in the CDR regions of humanized 2H7.v16 measured using cell-based ELISA (WIL2-S cells). The relative binding is expressed as the concentration of the 2H7.v16 parent over the concentration of the variant required for equivalent binding; hence a ratio <1 indicates weaker affinity for the variant; a ratio >1 indicates higher affinity for the variant. Standard deviation in relative affinity determination averaged +/- 10%. Framework substitutions in the variable domains are relative to  
 25     2H7.v16 according to the numbering system of Kabat (Kabat et al., *supra*). NDB means no detectable binding. The two numbers for version 45 are from separate experiments.

2H7 version	CDR location	Heavy chain substitutions	Light chain substitutions	Relative binding
16	-	-	-	-1-
140	H1	G26A	-	0.63
141	H1	Y27A	-	0.47
34	H1	T28A	-	0.86
35	H1	F29A	-	0.07
36	H1	T30A	-	0.81
37	H1	S31A	-	0.97
142	H1	Y32A	-	0.63
143	H1	N33A	-	NDB
144	H1	M34A	-	1.2
145	H1	H35A	-	<0.25
146	H2	A50G	-	0.31
147	H2	I51A	-	0.65

38	H2	Y52A	-	0.01
148	H2	P52aA	-	0.66
39	H2	G53A	-	0.89
67	H2	N54A	-	1.4
40	H2	G55A	-	0.79
41	H2	D56A	-	2.0
89	H2	T57A	-	0.61
90	H2	S58A	-	0.92
91	H2	Y59A	-	0.74
92	H2	N60A	-	0.80
93	H2	Q61A	-	0.83
94	H2	K62A	-	0.44
95	H2	F63A	-	0.51
83	H2	V71A	-	0.96
149	H2	K64A	-	0.82
150	H2	G65A	-	1.2
153	H3	V95A	-	0.89
42	H3	V96A	-	0.98
43	H3	Y97A	-	0.63
44	H3	Y98A	-	0.40
45	H3	S99A	-	0.84; 0.92
46	H3	N100A	-	0.81
47	H3	S100aA	-	0.85
48	H3	Y100bA	-	0.78
49	H3	W100cA	-	0.02
59	H3	Y100dA	-	0.98
60	H3	F100eA	-	NDB
61	H3	D101A	-	0.31
151	H3	V102A	-	1.1
117	L1	-	R24A	0.85
118	L1	-	A25G	0.86
119	L1	-	S26A	0.98
120	L1	-	S27A	0.98
121	L1	-	S28A	1.0
122	L1	-	V29A	0.41
50	L1	-	S30A	0.96
51	L1	-	Y32A	1.0
123	L1	-	M33A	1.0
124	L1	-	H34A	0.21
125	L2	-	A50G	0.92
126	L2	-	P51A	0.88
52	L2	-	S52A	0.80
53	L2	-	N53A	0.76
54	L2	-	L54A	0.60
127	L2	-	A55G	1.1
128	L2	-	S56A	1.1

129	L3	-	Q89A	0.46
130	L3	-	Q90A	<0.22
55	L2	-	W91A	0.88
56	L3	-	S92A	1.1
57	L3	-	F93A	0.36
58	L3	-	N94A	0.61
131	L3	-	P95A	NDB
132	L3	-	P96A	0.18
133	L3	-	T97A	<0.22

5

**Example 3****Additional mutations within 2H7 CDR regions**

Substitutions of additional residues and combinations of substitutions at CDR positions that were identified as important by Ala-scanning were also tested. Several combination variants, particularly v.96  
10 appeared to bind more tightly than v.16.

**Table 5.** Effects of combinations of mutations and non-alanine substitutions in the CDR regions of humanized 2H7.v16 measured using cell-based ELISA (WIL2-S cells). The relative binding to CD20 is expressed as the concentration of the 2H7.v16 parent over the concentration of the variant required for  
15 equivalent binding; hence a ratio <1 indicates weaker affinity for the variant; a ratio >1 indicates higher affinity for the variant. Standard deviation in relative affinity determination averaged +/- 10%. Framework substitutions in the variable domains are relative to 2H7.v16 according to the numbering system of Kabat (Kabat et al., *supra*).

2H7 version	Heavy chain substitutions	Light chain substitutions	Relative binding
16	-	-	-1-
96	D56A, N100A	S92A	3.5
97	S99T, N100G, Y100bI	-	0.99
98	S99G, N100S, Y100bI	-	1.6
99	N100G, Y100bI	-	0.80
101	N54S, D56A	-	1.7
102	N54K, D56A	-	0.48
103	D56A, N100A	-	2.1
104	S99T, N100G	-	0.81
105	S99G, N100S	-	1.1
106	N100G	-	~ 1
167	S100aG, Y100bS	-	
136	D56A, N100A	S56A, S92A	2.6
137	D56A, N100A	A55G, S92A	2.1
156	D56A, N100A	S26A, S56A, S92A	2.1
107	D56A, N100A, Y100bI	S92A	not expressed
182	Y27W	-	

183	Y27F	-	
184	F29Y	-	
185	F29W	-	
186	Y32F	-	
187	Y32W	-	
188	N33Q	-	
189	N33D	-	
190	N33Y	-	
191	N33S	-	
208	H35S	-	
209	A50S	-	
210	A50R	-	
211	A50V	-	
212	A50L	-	
168	Y52W	-	
169	Y52F	-	0.75
170	N54D	-	0.25
171	N54S	-	1.2
172	D56K	-	1
173	D56R	-	
174	D56H	-	1.5
175	D56E	-	1.2
213	D56S	-	
214	D56G	-	
215	D56N	-	
216	D56Y	-	
176	Y59W	-	
177	Y59F	-	
180	K62R	-	
181	K62D	-	
178	F63W	-	
179	F63Y	-	
157	Y97W	-	0.64
158	Y97F	-	1.2
159	Y98W	-	0.64
160	Y98F	-	0.88
106	N100G	-	
161	W100cY	-	0.05
162	W100cF	-	0.27
163	F100eY	-	0.59
164	F100eW	-	0.71
165	D101N	-	0.64
166	S99G, N100G, S100aD, Y100b deleted	-	0.99
217	V102Y	-	1.0
207	-	H34Y	

192	-	Q89E	
193	-	Q89N	
194	-	Q90E	
195	-	Q90N	
196	-	W91Y	
197	-	W91F	
205	-	S92N	
206	-	S92G	
198	-	F93Y	
199	-	F93W	
204	-	F93S, N94Y	
200	-	P96L	
201	-	P96Y	
202	-	P96W	
203	-	P96R	

5

**Example 4**  
**Mutations at sites of framework humanization substitutions**

Substitutions of additional residues at framework positions that were changed during humanization  
10 were also tested in the 2H7.v16 background. In particular, alternative framework substitutions that were neither found in the murine 2H7 parent nor the human consensus framework were made at V<sub>L</sub>(P46) and V<sub>H</sub>(G49, V71, and K73).

These substitutions generally led to little change in relative binding (Table 6), indicating that there is some flexibility in framework residues at these positions.

15

**Table 6.** Relative binding in a cell-based (WIL2-S) assay of framework substitutions. IgG variants are shown with mutations with respect to the 2H7.v16 background. The relative binding is expressed as the concentration of the 2H7.v6.8 chimera over the concentration of the variant required for equivalent binding; hence a ratio <1 indicates weaker affinity for the variant; a ratio >1 indicates higher affinity for the variant.

20 Standard deviation in relative affinity determination averaged +/- 10%. Framework substitutions in the variable domains are relative to 2H7.v16 according to the numbering system of Kabat (Kabat et al., *supra*). (\*) Variants that were assayed with 2H7.v16 as the standard comparator; relative values are normalized to that of the chimera.

2H7 version	Heavy chain substitutions	Light chain substitutions	Relative binding
6.8	(chimera)	(chimera)	-1-
16	-	-	0.64
78	K73R	-	0.72
79	K73H	-	0.49
80	K73Q	-	0.58
81	V71I	-	0.42
82	V71T	-	0.58
83	V71A	-	
84	G49S	-	0.32

85	G49L	-	
86	-	P46E	0.22
87	-	P46V	0.51
88	-	P46T	
108	G49A, V71T, K73R	S92A, M32L, P46T	0.026*
109	G49A, A49G, V71T, K73R	S92A, M32L, P46T	0.026*
110	K73R, D56A, N100A	S92A, M32L	Not expressed
111	G49A, V71T, K73R	-	0.46*
112	G49A, A50G, V71T, K73R	-	0.12*

(\*) Variants that were assayed with 2H7.v16 as the standard comparator;  
relative values are normalized to that of the chimera.

5

### Example 5

#### **Humanized 2H7 variants with enhanced effector functions**

Because 2H7 can mediate lysis of B-cells through both complement-dependent cytotoxicity (CDC) and antibody-dependent cellular cytotoxicity (ADCC), we sought to produce variants of humanized 2H7.v16 with improved CDC and ADCC activity. Mutations of certain residues within the Fc regions of other antibodies have been described (Idusogie et al., *J. Immunol.* 166:2571-2575 (2001)) for improving CDC through enhanced binding to the complement component C1q. Mutations have also been described (Shields et al., *J. Biol. Chem.* 276:6591-6604 (2001); Presta et al., *Biochem. Soc. Trans.* 30:487-490 (2002)) for improving ADCC through enhanced IgG binding to activating Fc $\gamma$  receptors and reduced IgG binding to inhibitory Fc $\gamma$  receptors. In particular, three mutations have been identified for improving CDC and ADCC activity: S298A/E333A/K334A (also referred to herein as a triple Ala mutant or variant; numbering in the Fc region is according to the EU numbering system; Kabat et al., *supra*) as described (Idusogie et al., *supra* (2001); Shields et al., *supra*).

In order to enhance CDC and ADCC activity of 2H7, a triple Ala mutant of the 2H7 Fc was constructed. A humanized variant of the anti-HER2 antibody 4d5 has been produced with mutations S298A/E333A/K334A and is known as 4D5Fc110 (*i.e.*, anti-p<sup>185</sup>HER2 IgG1 (S298A/E333A/K334A); Shields et al., *supra*). A plasmid, p4D5Fc110 encoding antibody 4D5Fc110 (Shields et al., *supra*) was digested with *Apal* and *HindIII*, and the Fc-fragment (containing mutations S298A/E333A/K334A) was ligated into the *Apal/HindIII* sites of the 2H7 heavy-chain vector pDR2-v16, to produce pDR2-v31. The amino acid sequence of the version 31 complete H chain is shown in Fig. 8. The L chain is the same as that of v16.

Although the constant domains of the Fc region of IgG1 antibodies are relatively conserved within a given species, allelic variations exist (reviewed by Lefranc and Lefranc, in *The human IgG subclasses: molecular analysis of structure, function, and regulation*, pp. 43-78, F. Shakib (ed.), Pergamon Press, Oxford (1990)).

**Table 7.** Effects of substitutions in the Fc region on CD20 binding. Relative binding to CD20 was measured in a cell-based (WIL2-S) assay of framework substitutions. Fc mutations (\*) are indicated by EU numbering (Kabat, *supra*) and are relative to the 2H7.v16 parent. The combination of three Ala changes in

5 the Fc region of v.31 is described as "Fc110." IgG variants are shown with mutations with respect to the 2H7.v16 background. The relative binding is expressed as the concentration of the 2H7.v6.8 chimera over the concentration of the variant required for equivalent binding; hence a ratio <1 indicates weaker affinity for the variant. Standard deviation in relative affinity determination averaged +/- 10%.

2H7 version	Fc Substitutions*	Relative binding
6.8	-	-1-
16	-	0.65
31	S298A, E333A, K334A	0.62

10

#### Example 6

##### **Humanized 2H7 variants with enhanced stability**

For development as therapeutic proteins, it is desirable to choose variants that remain stable with respect to oxidation, deamidation, or other processes that may affect product quality, in a suitable 15 formulation buffer. In 2H7.v16, several residues were identified as possible sources of instability: VL (M32) and VH (M34, N100). Therefore, mutations were introduced at these sites for comparison with v16.

20 **Table 8.** Relative binding of 2H7 variants designed for enhanced stability and/or effector function, to CD20 in a cell-based (WIL2-S) assay. IgG variants are shown with mutations with respect to the 2H7.v16 background. The relative binding is expressed as the concentration of the 2H7.v6.8 chimera over the concentration of the variant required for equivalent binding; hence a ratio <1 indicates weaker affinity for the variant. Standard deviation in relative affinity determination averaged +/- 10%. Framework 25 substitutions in the variable domains are relative to 2H7.v16 according to the numbering system of Kabat and Fc mutations (\*) are indicated by EU numbering (Kabat et al., *supra*). (\*\*) Variants that were measured with 2H7.v16 as the standard comparator; relative values are normalized to that of the chimera.

Additional Fc mutations were combined with stability or affinity-enhancing mutations to alter or enhance effector functions based on previously reported mutations (Idusogie et al. (2000); Idusogie et al. (2001); Shields et al. (2001)). These changes include S298, E333A, K334A as described in Example 5; K322A to reduced CDC activity; D265A to reduce ADCC activity; K326A or K326W to 30 enhance CDC activity; and E356D/M358L to test the effects of allotypic changes in the Fc region. None of these mutations caused significant differences in CD20 binding affinity.

2H7 version	Heavy chain (V <sub>H</sub> ) changes	Light chain (V <sub>L</sub> ) changes	Fc changes *	Relative binding
6.8	(chimera)	(chimera)	-	-1-
16	-	-	-	0.65
62	-	M32I	-	0.46
63	M34I	-	-	0.49
64	N100A	-	-	
65	N100A	L47W	-	0.74
66	S99A	L47W	-	0.62
67	N54A	-	-	

68	-	M32I	-	0.48
69	-	M32L	-	0.52
70	N100A	-	S298A, E333A, K334A	0.80
71	N100D	-	S298A, E333A, K334A	0.44
72	N100A	M32I	-	0.58
73	N100A	M32L	-	0.53
74	N100A	M32I	S298A, E333A, K334A	0.61
75	N100A	M32L	S298A, E333A, K334A	0.60
113	-	-	E356D, M358L	0.60**
114	D56A, N100A	M32L, S92A	S298A, E333A, K334A	1.2**
115	D56A, N100A	M32L, S92A	S298A, E333A, K334A, E356D, M358L	1.4**
116	D56A, N100A	M32L, S92A	S298A, K334A, K322A	1.2**
134	D56A, N100A	M32L, S92A	E356D, M358L, D265A	1.5**
135	D56A, N100A	M32L, S92A	E356D, M358L, D265A, K326W	0.95**
138	D56A, N100A	M32L, S92A	S298A, E333A, K334A, K326A	1.2**
139	D56A, N100A	M32L, S92A	S298A, E333A, K334A, K326A, E356N, M358L	1.1**
154	-	-	D265A	0.70**
155	-	-	S298A, K322A, K334A	0.70**

(\*\*) Variants that were measured with 2H7.v16 as comparator;  
relative binding values are normalized to that of the chimera.

5

To test the effects of stability mutations on the rate of protein degradation, 2H7.v16 and 2H7.v73 were formulated at 12-14 mg/mL in 10 mM histidine, 6% sucrose, 0.02% polysorbate 20, pH 5.8 and incubated at 40°C for 16 days. The incubated samples were then assayed for changes in charge variants by ion exchange chromatography, aggregation and fragmentation by size exclusion chromatography, and relative binding by testing in a cell-based (WIL2-S) assay.

10

The results (Fig. 9) show that 2H7 v.73 has greater stability compared to 2H7 v.16 with respect to losses in the fraction of main peak by ion exchange chromatography under accelerated stability conditions. No significant differences were seen with respect to aggregation, fragmentation, or binding affinity.

15

### Example 7 Scatchard analysis of antibody binding to CD20 on WIL2-S cells

Equilibrium dissociation constants ( $K_d$ ) were determined for 2H7 IgG variants binding to WIL2-S cells using radiolabeled 2H7 IgG. IgG variants were produced in CHO cells. Rituxan® (source for all experiments is Genentech, S. San Francisco, CA) and murine 2H7 (BD PharMingen, San Diego, CA) were used for comparison with humanized variants. The murine 2H7 antibody is also available from other sources, e.g., eBioscience, and Calbiochem (both of San Diego, CA), Accurate Chemical & Scientific Corp., (Westbury, NY), Ancell (Bayport, MN), and Vinci-Biochem (Vinci, Italy). All dilutions were performed in binding assay buffer (DMEM media containing 1% bovine serum albumin, 25 mM HEPES pH 7.2, and 0.01% sodium azide). Aliquots (0.025 mL) of  $^{125}\text{I}$ -2H7.v16 (iodinated with lactoperoxidase) at a concentration of 0.8 nM were dispensed into wells of a V-bottom 96-well microassay plate, and serial dilutions (0.05 mL) of cold antibody were added and mixed. WIL2-S cells (60,000 cells in 0.025 mL) were then added. The plate was sealed and incubated at room temperature for 24h, then centrifuged for 15 min at 3,500 RPM. The supernatant was then aspirated and the cell pellet was washed and centrifuged. The

5 supernatant was again aspirated, and the pellets were dissolved in 1N NaOH and transferred to tubes for gamma counting. The data were used for Scatchard analysis (Munson and Rodbard, *Anal. Biochem.* 107:220-239 (1980)) using the program Ligand (McPherson, *Comput. Programs Biomed.* 17: 107-114 (1983)). The results, shown in Table 9, indicate that humanized 2H7 variants had similar CD20 binding affinity as compared to murine 2H7, and similar binding affinity to Rituxan®. It is expected that 2H7.v31  
10 will have very similar K<sub>d</sub> to v.16 on the basis of the binding shown in Table 7 above.

**Table 9.** Equilibrium binding affinity of 2H7 variants from Scatchard analysis

Antibody variant	K <sub>d</sub> (nM)	n
Rituxan	0.99±0.49	3
2H7 (murine)	1.23±0.29	3
2H7.v16	0.84±0.37	4
2H7.v73	1.22±0.39	4
2H7.v75	1.09±0.17	4

**Example 8**

**Complement Dependent Cytotoxicity (CDC) Assays**

15 2H7 IgG variants were assayed for their ability to mediate complement-dependent lysis of WIL2-S cells, a CD20 expressing lymphoblastoid B-cell line, essentially as described (Idusogie et al., *J. Immunol.* 164:4178-4184 (2000); Idusogie et al., *J. Immunol.* 166:2571-2575 (2001)). Antibodies were serially diluted 1:3 from a 0.1 mg/mL stock solution. A 0.05 mL aliquot of each dilution was added to a 96-well tissue culture plate that contained 0.05 mL of a solution of normal human complement (Quidel, San Diego, CA)  
20 To this mixture, 50,000 WIL2-S cells were added in a 0.05 mL volume. After incubation for 2h at 37°C, 0.05 mL of a solution of Alamar blue (Accumed International, Westlake, OH) was added, and incubation was continued for an additional 18h at 37°C. Covers were then removed from the plates, and they were shaken for 15 min at room temperature on an orbital shaker. Relative fluorescent units (RFU) were read  
25 using a 530 nm excitation filter and a 590 nm emission filter. An EC<sub>50</sub> was calculated by fitting RFU as a function of concentration for each antibody using KaleidaGraph software.

The results (Table 10) show surprising improvement in CDC by humanized 2H7 antibodies, with relative potency similar to Rituxan® for v.73, 3-fold more potent than Rituxan® for v.75, and 3-fold weaker than Rituxan® for v.16.

30 **Table 10.** CDC activity of 2H7 antibodies compared to Rituxan. Numbers >1 indicate less potent CDC activity than Rituxan® and numbers <1 indicate more potent activity than Rituxan®. Antibodies were produced from stable CHO lines, except that those indicated by (\*) were produced transiently .

Antibody variant	n	EC <sub>50</sub> (variant)/EC <sub>50</sub> (Rituxan)
Rituxan®	4	-1-
2H7.v16	4	3.72; 4.08
2H7.v31*	4	2.21
2H7.v73	4	1.05
2H7.v75	4	0.33

2H7.v96*	4	0.956
2H7.v114*	4	0.378
2H7.v115*	4	0.475
2H7.v116*	1	>100
2H7.v135*	2	0.42

5

**Example 9**  
**Antibody Dependent Cellular Cytotoxicity (ADCC) Assays**

2H7 IgG variants were assayed for their ability to mediate Natural-Killer cell (NK cell) lysis of  
10 WIL2-S cells, a CD20 expressing lymphoblastoid B-cell line, essentially as described (Shields et al., *J. Biol. Chem.* 276:6591-6604 (2001)) using a lactate dehydrogenase (LDH) readout. NK cells were prepared from  
100 mL of heparinized blood, diluted with 100 mL of PBS (phosphate buffered saline), obtained from  
normal human donors who had been isotyping for FcγRIII, also known as CD16 (Koene et al., *Blood*  
90:1109-1114 (1997)). In this experiment, the NK cells were from human donors heterozygous for CD16  
15 (F158/V158). The diluted blood was layered over 15 mL of lymphocyte separation medium (ICN  
Biochemical, Aurora, Ohio) and centrifuged for 20 min at 2000 RPM. White cells at the interface between  
layers were dispensed to 4 clean 50-mL tubes, which were filled with RPMI medium containing 15% fetal  
calf serum. Tubes were centrifuged for 5 min at 1400 RPM and the supernatant discarded. Pellets were  
resuspended in MACS buffer (0.5% BSA, 2mM EDTA), and NK cells were purified using beads (NK Cell  
20 Isolation Kit, 130-046-502) according to the manufacturer's protocol (Miltenyi Biotech.). NK cells were  
diluted in MACS buffer to  $2 \times 10^6$  cells/mL.

Serial dilutions of antibody (0.05 mL) in assay medium (F12/DMEM 50:50 without glycine, 1 mM  
HEPES buffer pH 7.2, Penicillin/Streptomycin (100 units/mL; Gibco), glutamine, and 1% heat-inactivated  
25 fetal bovine serum) were added to a 96-well round-bottom tissue culture plate. WIL2-S cells were diluted in  
assay buffer to a concentration of  $4 \times 10^5$ /mL. WIL2-S cells (0.05 mL per well) were mixed with diluted  
antibody in the 96-well plate and incubated for 30 min at room temperature to allow binding of antibody to  
CD20 (opsonization).

The ADCC reaction was initiated by adding 0.1 mL of NK cells to each well. In control wells, 2%  
Triton X-100 was added. The plate was then incubated for 4h at 37°C. Levels of LDH released were  
30 measured using a cytotoxicity (LDH) detection kit (Kit#1644793, Roche Diagnostics, Indianapolis, Indiana.)  
following the manufacturers instructions. 0.1 mL of LDH developer was added to each well, followed by  
mixing for 10s. The plate was then covered with aluminum foil and incubated in the dark at room  
temperature for 15 min. Optical density at 490 nm was then read and used to calculate % lysis by dividing by  
the total LDH measured in control wells. Lysis was plotted as a function of antibody concentration, and a 4-  
35 parameter curve fit (KaleidaGraph) was used to determine EC<sub>50</sub> concentrations.

The results showed that humanized 2H7 antibodies were active in ADCC, with relative potency 20-fold higher than Rituxan® for v.31 and v.75, 5-fold more potent than Rituxan® for v.16, and almost 4-fold higher than Rituxan® for v.73.

5           **Table 11.** ADCC activity of 2H7 antibodies on WIL2-S cells compared to 2H7.v16, based on n experiments. (Values >1 indicate lower potency than 2H7.v16, and values <1 indicate greater potency.)

Antibody variant	n	EC <sub>50</sub> (variant)/EC <sub>50</sub> (2H7.v16)
Rituxan®	4	5.3
2H7.v16	5	1
2H7.v31	1	0.24
2H7.v73	5	1.4
2H7.v75	4	0.25

Additional ADCC assays were carried out to compare combination-variants of 2H7 with Rituxan®.

10       The results of these assays indicated that 2H7.v114 and 2H7.v115 have >10-fold improved ADCC potency as compared to Rituxan® (Table 12).

15           **Table 12.** ADCC activity of 2H7 antibodies on WIL2-S cells compared to Rituxan®, based on n experiments (Values >1 indicate lower potency than Rituxan®, and values <1 indicate greater potency).

Antibody variant	EC50(variant)/EC50(Rituxan)
Rituxan®	2
2H7 v.16	2      0.52
2H7 v.96	2      0.58
2H7.v114	2      0.093
2H7.v115	2      0.083
2H7.v116	2      0.30

#### Example 10

##### **In vivo effects of 2H7 variants in a pilot study in cynomolgus monkeys**

20       2H7 variants, produced by transient transfection of CHO cells, were tested in normal male cynomolgus (*Macaca fascicularis*) monkeys in order to evaluate their *in vivo* activities. Other anti-CD20 antibodies, such as C2B8 (Rituxan®) have demonstrated an ability to deplete B-cells in normal primates (Reff et al., *Blood* 83: 435-445 (1994)).

25       In one study, humanized 2H7 variants were compared. In a parallel study, Rituxan® was also tested in cynomolgus monkeys. Four monkeys were used in each of five dose groups: (1) vehicle, (2) 0.05 mg/kg hu2H7.v16, (3) 10 mg/kg hu2H7.v16, (4) 0.05 mg/kg hu2H7.v31, and (5) 10 mg/kg hu2H7.v31. Antibodies were administered intravenously at a concentration of 0, 0.2, or 20 mg/mL, for a total of two doses, one on day 1 of the study, and another on day 8. The first day of dosing is designated day 1 and the previous day is designated day -1; the first day of recovery (for 2 animals in each group) is designated as day 11. Blood samples were collected on days -19, -12, 1 (prior to dosing), and at 6h, 24h, and 72h following the first dose. Additional samples were taken on day 8 (prior to dosing), day 10 (prior to sacrifice of 2 animals/group), and on days 36 and 67 (for recovery animals).

30       Peripheral B-cell concentrations were determined by a FACS method that counted CD3-/CD40+ cells. The percent of CD3-CD40+ B cells of total lymphocytes in monkey samples were obtained by the following gating strategy. The lymphocyte population was marked on the forward scatter/ side scatter

5 scattergram to define Region 1 (R1). Using events in R1, fluorescence intensity dot plots were displayed for CD40 and CD3 markers. Fluorescently labeled isotype controls were used to determine respective cutoff points for CD40 and CD3 positivity.

The results indicated that both 2H7.v16 and 2H7.v31 were capable of producing full peripheral B-cell depletion at the 10 mg/kg dose and partial peripheral B-cell depletion at the 0.05 mg/kg dose (Fig. 11).

10 The time course and extent of B-cell depletion measured during the first 72h of dosing were similar for the two antibodies. Subsequent analysis of the recovery animals indicated that animals treated with 2H7.v31 showed a prolonged depletion of B-cells as compared to those dosed with 2H7.v16. In particular, recovery animals treated with 10 mg/kg 2H7.v16, B-cells showed substantial B-cell recovery at some time between sampling on Day 10 and on Day 36. However, for recovery animals treated with 10 mg/kg 2H7.v31, B-cells  
15 did not show recovery until some time between Day 36 and Day 67 (Fig. 11). This suggests a greater duration of full depletion by about one month for 2H7.v31 compared to 2H7.v16.

No toxicity was observed in the monkey study at low or high dose and the gross pathology was normal. In other studies, v16 was well tolerated up to the highest dose evaluated of (100mg/kgx2 = 1200 mg/m<sup>2</sup> x2) following i.v. administration of 2 doses given 2 weeks apart in these monkeys.

20 Data in Cynomolgus monkeys with 2H7.v16 versus Rituxan® suggests that a 5-fold reduction in CDC activity does not adversely affect potency. An antibody with potent ADCC activity but reduced CDC activity may have more favorable safety profile with regard to first infusion reactions than one with greater CDC activity.

25

### Example 11

#### Fucose deficient 2H7 variant antibodies with enhanced effector function

Normal CHO and HEK293 cells add fucose to IgG oligosaccharide to a high degree (97-98%). IgG from sera are also highly fucosylated.

DP12, a dihydrofolate reductase minus (DHFR<sup>-</sup>) CHO cell line that is fucosylation competent, and Lec13, a cell line that is deficient in protein fucosylation were used to produce antibodies for this study. The CHO cell line Pro-Lec13.6a (Lec13), was obtained from Professor Pamela Stanley of Albert Einstein College of Medicine of Yeshiva University. Parental lines are Pro- (proline auxotroph) and Gat- (glycine, adenosine, thymidine auxotroph). The CHO-DP12 cell line is a derivative of the CHO-K1 cell line (ATCC #CCL-61), which is dihydrofolate reductase deficient, and has a reduced requirement for insulin. Cell lines  
35 were transfected with cDNA using the Superfect method (Qiagen, Valencia, CA). Selection of the Lec13 cells expressing transfected antibodies was performed using puromycin dihydrochloride (Calbiochem, San Diego, CA) at 10 µg/ml in growth medium containing: MEM Alpha Medium with L-glutamine, ribonucleosides and deoxyribonucleosides (GIBCO-BRL, Gaithersburg, MD), supplemented with 10% inactivated FBS (GIBCO), 10 mM HEPES, and 1X penicillin/streptomycin (GIBCO). The CHO cells were  
40 similarly selected in growth medium containing Ham's F12 without GHT: Low Glucose DMEM without Glycine with NaHCO<sub>3</sub> supplemented with 5% FBS (GIBCO), 10 mM HEPES, 2 mM L-glutamine, 1X GHT(glycine, hypoxanthine, thymidine), and 1X penicillin/streptomycin.

Colonies formed within two to three weeks and were pooled for expansion and protein expression. The cell pools were seeded initially at 3 x 10<sup>6</sup> cells/10 cm plate for small batch protein expression. The cells

5 were converted to serum-free media once they grew to 90-95% confluence and after 3-5 days cell supernatants were collected and tested in an Fc IgG- and intact IgG-ELISA to estimate protein expression levels. Lec13 and CHO cells were seeded at approximately  $8 \times 10^6$  cells/15 cm plate one day prior to converting to PS24 production medium, supplemented with 10 mg/L recombinant human insulin and 1 mg/L trace elements.

10 Lec13 cells and DP12 cells remained in serum-free production medium for 3-5 days. Supernatants were collected and clarified by centrifugation in 150 ml conical tubes to remove cells and debris. The protease inhibitors PMSF and aprotinin (Sigma, St. Louis, MO) were added and the supernatants were concentrated 5-fold on stirred cells using MWCO30 filters (Amicon, Beverly, MA) prior to immediate purification using protein G chromatography (Amersham Pharmacia Biotech, Piscataway, NJ)). All proteins 15 were buffer exchanged into phosphate-buffered saline (PBS) using Centriprep-30 concentrators (Amicon) and analyzed by SDS-polyacrylamide gel electrophoresis. Protein concentrations were determined using A280 and verified using amino acid composition analysis.

The CHO cells were transfected with vectors expressing humanized 2H7v16, 2H7v.31 and selected as described. The 2H7v.16 antibody retains the wild type Fc region while v.31 (see Example 5, Table 7 20 above) has an Fc region wherein 3 amino acid changes were made (S298A, E333A, K334A) which results in higher affinity for the Fc<sub>γ</sub>RIIIa receptor (Shields et al. J. Biol. Chem. 276 (9):6591-6604 (2001)). Following transfection and selection, individual colonies of cells were isolated and evaluated for protein expression level and the highest producers were subjected to methotrexate selection to select for cells that had amplified the plasmid copy number and which therefore produced higher levels of antibody. Cells were grown, 25 transferred to serum free medium for a period of 7 days, then the medium was collected, loaded onto a protein A column and the antibody was eluted using standard techniques. The final concentration of the antibody was determined using an Elisa that measures intact antibody. All proteins were buffer exchanged into phosphate-buffered saline (PBS) using Centriprep-30 concentrators. (Amicon) and analyzed by SDS-polyacrylamide gel electrophoresis.

30 *Matrix-Assisted Laser Desorption/Ionization Time-of-flight (MALDI-TOF) Mass Spectral Analysis of Asparagine-Linked Oligosaccharides:* N-linked oligosaccharides were released from recombinant glycoproteins using the procedure of Papac et al., *Glycobiology* 8, 445-454 (1998). Briefly, the wells of a 96 well PVDF-lined microtitre plate (Millipore, Bedford, MA) were conditioned with 100 µl methanol that was drawn through the PDVF membranes by applying vacuum to the Millipore Multiscreen vacuum manifold. 35 The conditioned PVDF membranes were washed with 3 X 250 µl water. Between all wash steps the wells were drained completely by applying gentle vacuum to the manifold. The membranes were washed with reduction and carboxymethylation buffer (RCM) consisting of 6 M guanidine hydrochloride, 360 mM Tris, 2 mM EDTA, pH 8.6. Glycoprotein samples (50 µg) were applied to individual wells, again drawn through the PVDF membranes by gentle vacuum and the wells were washed with 2 X 50 µl of RCM buffer. The 40 immobilized samples were reduced by adding 50 µl of a 0.1 M dithiothreitol (DTT) solution to each well and incubating the microtitre plate at 37°C for 1 hr. DTT was removed by vacuum and the wells were washed 4 x 250 µl water. Cysteine residues were carboxymethylated by the addition of 50 µl of a 0.1 M iodoacetic acid (IAA) solution which was freshly prepared in 1 M NaOH and diluted to 0.1 M with RCM buffer. Carboxymethylation was accomplished by incubation for 30 min in the dark at ambient temperature.

5 Vacuum was applied to the plate to remove the IAA solution and the wells were washed with 4 x 250 µl purified water. The PVDF membranes were blocked by the addition of 100 µl of 1% PVP360 (polyvinylpyrrolidine 360,000 MW) (Sigma) solution and incubation for 1 hr at ambient temperature. The PVP-360 solution was removed by gentle vacuum and the wells were washed 4 x 250 µl water. The PNGase F (New England Biolabs, Beverly, MA) digest solution, 25 µl of a 25 Unit/ml solution in 10 mM Tris acetate, pH 8.4, was added to each well and the digest proceeded for 3 hr at 37°C. After digestion, the samples were transferred to 500 µl Eppendorf tubes and 2.5 µL of a 1.5 M acetic acid solution was added to each sample. The acidified samples were incubated for 3 hr at ambient temperature to convert the oligosaccharides from glycosylamines to the hydroxyl form. Prior to MALDI-TOF mass spectral analysis, the released oligosaccharides were desalted using a 0.7-ml bed of cation exchange resin (AG50W-X8 resin in the hydrogen form) (Bio-Rad, Hercules, CA) slurried packed into compact reaction tubes (US Biochemical, Cleveland, OH).

For MALDI-TOF mass spectral analysis of the samples in the positive mode, the desalted oligosaccharides (0.5 µl aliquots) were applied to the stainless target with 0.5 µl of the 2,5 dihydroxybenzoic acid matrix (sDHB) that was prepared by dissolving 2 mg 2,5 dihydroxybenzoic acid with 0.1 mg of 5-methoxyslsicylic acid in 1 ml of ethanol/10 mM sodium chloride 1:1 (v/v). The sample/matrix mixture was dried by vacuum. For analysis in the negative mode, the desalted N-linked oligosaccharides (0.5 µl aliquots) were applied to the stainless target along with 0.5 µl 2',4',6'-trihydroxyacetophenone matrix (THAP) prepared in 1:3 (v/v) acetonitrile/13.3 mM ammonium citrate buffer. The sample/matrix mixture was vacuum dried and then allowed to absorb atmospheric moisture prior to analysis. Released oligosaccharides were analyzed by MALDI-TOF on a PerSeptive BioSystems Voyager-DE mass spectrometer. The mass spectrometer was operated at 20 kV either in the positive or negative mode with the linear configuration and utilizing delayed extraction. Data were acquired using a laser power of 1300 and in the data summation mode (240 scans) to improve the signal to noise. The instrument was calibrated with a mixture of standard oligosaccharides and the data was smoothed using a 19 point Savitsky-Golay algorithm before the masses were assigned. Integration of the mass spectral data was achieved using Caesar 7.0 data analysis software package (SciBridge Software).

*Natural killer (NK) cell antibody dependent cytotoxicity assays.*

ADCC assays were performed as described in Example 9. NK to target cell (WIL2-S) ratio was 4 to 1, assays were run for 4 hours, and toxicity was measured as before using lactose dehydrogenase assay. Target cells were opsonized with the concentrations of antibody indicated for 30 min prior to addition of NK cells. The Rituxan® antibody used was from Genentech (S. San Francisco, CA). Figure 12 shows the results of a representative ADCC assay.

The results show that underfucosylated antibodies mediate NK cell target cell killing more efficiently than do antibodies with a full complement of fucose. The underfucosylated antibody, 2H7v.31, is most efficient at mediating target cell killing. This antibody is effective at lower concentrations and is capable of mediating killing of a greater percentage of target cells at higher concentrations than are the other antibodies. The activity of the antibodies is as follows: Lec13-derived 2H7 v31 > Lec 13 derived 2H7v16 > Dp12 derived 2H7v31 > Dp12 derived 2H7v16 > or = to Rituxan. The protein and carbohydrate alterations are additive. Comparison of the carbohydrate found on native IgG from the Lec13-produced and CHO-

5 produced IgG showed no appreciable differences in the extent of galactosylation and hence the results can be attributed solely to the presence/absence of fucose.

### Example 12

#### **Fucose-deficient 2H7 variant antibodies with enhanced ADCC in vivo**

10 This example describes ADCC activity in vivo of the fucose-deficient humanized 2H7 variants including v.16 and v.31 produced in Lec13 compared to normal fucosylated counterparts produced in DP12, in mice expressing human CD16 [FcR $\gamma$ III] and human CD20.

##### *Generation of huCD20Tg<sup>+</sup> huCD16Tg<sup>+</sup> mCD16<sup>-/-</sup> mice*

15 Human CD20 transgenic mice were generated from human CD20 BAC DNA (Invitrogen, Carlsbad, CA). Mice were screened based on the FACS analysis of human CD20 expression. HuCD20 Tg<sup>+</sup> mice were then crossed with huCD16Tg<sup>+</sup> mCD16<sup>-/-</sup> mice to generate huCD20Tg<sup>+</sup> huCD16Tg<sup>+</sup> mCD16<sup>-/-</sup> mice.

##### *In vivo treatment*

20 Ten to 100 µg of each of the 2H7 variants or Rituxan® is administrated to huCD20Tg<sup>+</sup> huCD16Tg<sup>+</sup> mCD16<sup>-/-</sup> mice via intraperitoneal injections. Equal amount of isotype-matched antibodies will be applied similarly to the negative control group of animals.

##### *Mouse lymphocytes preparation*

25 Mouse lymphocytes from whole blood, spleen, lymph nodes and bone marrow are prepared according to standard protocol described in "Current Protocols in Immunology, edited by John Coligan, Ada Kruijsbeek, David Margulies, Ethan Shevach and Warren Strober, 1994".

##### *FACS analysis*

Half million cells are washed and resuspended in 100 µl of FACS buffer, which is phosphate buffered saline with 1% BSA, containing 5 µl of staining or control antibody. All the staining antibodies, including isotype controls, are obtained from PharMingen, San Diego, CA. Human CD20 expression is assessed by staining with Rituxan® along with FITC-conjugated anti-human IgG1 secondary antibody. 30 FACS analysis is conducted using FACScan and Cell Quest (Becton Dickinson Immunocytometry Systems, San Jose, CA). All the lymphocytes are defined in the forward and side light scatterings, while all the B lymphocytes are defined with the expression of B220 on the cell surface.

35 B cell depletion and recovery are assessed by analyzing peripheral B cell counts and analysis of hCD20+ B cells by FACS in the spleen, lymph node and bone marrow on a daily basis for the first week after injection and thereafter on a weekly basis. Serum levels of the injected 2H7 variant antibody are monitored.

The results of this in vivo assay confirms the in vitro findings on the increased ADCC activity and greater B cell depletion of fucose-deficient 2H7 variants over wild-type (with respect to fucosylation) glycosylation counterparts.

Example 13**Apoptosis Activity**

Anti-CD20 antibodies including Rituxan® have been shown to induce *apoptosis in vitro* when crosslinked by a secondary antibody or by chemical means (Shan et al., Blood 9:1644-1652 (1998); Byrd et al., Blood 99:1038-43 (2002); Pederson et al., Blood 99:1314-19 (2002)). When chemically crosslinked, murine 2H7 dimers induced apoptosis of Daudi cells (Ghetie et al., Proc Natl Acad Sci USA 94:7509-14 (1997)). Crosslinking with a secondary antibody also induced apoptosis with the murine 2H7 antibody (Shan et al., 1998). These activities are believed to be physiologically relevant because a variety of mechanisms could lead to crosslinking of anti-CD20 antibodies bound to cell-surface CD20 *in vivo*.

RhuMAb 2H7.v16 [humanized 2H7 v16; RhuMAb stands for recombinant human monoclonal antibody] and Rituxan® were compared in apoptosis assays *in vitro* using a secondary crosslinking antibody. Ramos cells (CRL-1596, ATCC, Manassas, VA), a CD20-expressing, human B lymphocyte cell line, were used to measure the ability of the anti-CD20 monoclonal antibodies rhuMAb 2H7.v16 and Rituximab versus a negative-control antibody, Trastuzumab (Herceptin®, Genentech, South San Francisco, CA), to induce apoptosis as measured through Annexin V staining and propidium iodide dye exclusion (Vybrant® Apoptosis Assay Kit, Molecular Probes, Seattle, WA). The Ramos cells were cultured in RPMI-1640 medium (Gibco, Rockville, MD) containing 10% fetal bovine serum (Biosource International, Camarillo, CA) and 2 mM L-glutamine (Gibco). Prior to being assayed, the cells were washed twice in fresh media and then adjusted to a cell concentration of  $2 \times 10^6$  per mL. Cells (150 µL) were added to 96-well assay plates (Becton Dickinson, Palo Alto, CA) which contained 150 µL of a predetermined amount of control IgG1, rhuMAb 2H7.v16, or Rituximab, along with F(ab)'2 goat anti-human Fc (Pierce Biotechnology, Rockford, IL). The final IgG concentrations were 100, 10, 1.0, 0.1, 0.01 and 0.001 nM, and the F(ab)'2 goat anti-human Fc antibody concentration was set at twice the respective sample antibody concentration. Each dilution was set up in triplicate. After a 24-hour incubation at 37° C, the cells were washed twice with PBS and then stained with Annexin V and propidium iodide according to the manufacturer's recommendations. The staining patterns of the Ramos cells were analyzed by flow cytometry using a FACscan Flow Cytometer (Becton Dickinson, San Jose, CA), and data were collected for 10 s-periods. The data were reduced using the Cellquest Pro software (Becton Dickinson). Ramos cells that were positive for (1) Annexin V staining, (2) Annexin V and propiduum iodide double-staining, and (3) the number of unstained live cells, were counted and plotted using KaleidaGraph software (Synergy Software, Reading, PA).

Both rhuMAb 2H7.v16 and Rituximab induced apoptosis of Ramos cells when crosslinked with anti-human Fc and as compared to an irrelevant IgG1 control antibody (Figures 13-15). The apoptotic activity of (rhuMAb 2H7) was slightly lower than that of Rituximab. At 10 nM concentrations of crosslinked rhuMAb 2H7, Rituximab, and control IgG1 antibody, fractions of Annexin V stained cells were 18.5, 16.5, 2.5%, respectively, fractions of doubly labeled cells were 29, 38, and 16%, and numbers of live cells counted per 10 s were 5200, 3100, and 8600.

These *in vitro* data demonstrate that apoptosis is one potential mechanism for *in vivo* B cell depletion. *In vivo* crosslinking of rhuMAb 2H7 or Rituximab bound to cell-surface CD20 may occur through FcγR on the surfaces of immune effector cells.

5

Example 14**In Vivo Suppression of Tumor Growth**

The ability of rhuMAb 2H7.v16 to inhibit the growth of the Raji human B-cells, a lymphoma cell line (ATCC CCL 86), was evaluated in Balb/c nude (athymic) mice. The Raji cells express CD20 and have been reported to grow in nude mice, producing metastatic disease; tumor growth is inhibited by Rituxan® (Clynes et al., *Nature Medicine* 6, 443-446 (2000)). Fifty-six 8-10 week old, Balb/c nude mice were divided into 7 groups (A-G) with each group consisting of 8 mice. On day 0, each mouse received a subcutaneous injection of  $5 \times 10^6$  Raji B-lymphoma cells in the flank. Beginning at day 0, each mouse received either 100 uL of the negative-control solution (PBS; phosphate-buffered saline), Rituxan® or 2H7.v16. Dosage was dependent on weight and drug delivery was intravenously via the tail vein. Group A mice received PBS. Groups B-D received Rituxan® at 5.0 mg/kg, 0.5 mg/kg, and 0.05 mg/kg respectively. Groups E-G mice received 2H7 v.16 at 5.0 mg/kg, 0.5 mg/kg, and 0.05 mg/kg respectively. The injections were repeated every week for 6 weeks. At weekly intervals during treatment, each mouse was inspected for the presence of palpable tumors at the site of injection, and the volume of the tumors if present were measured and recorded. A final inspection was made at week 8 (after a two-week interval of no treatments).

The results of this study showed that both rhuMAb 2H7.v16 and Rituxan® and were effective at inhibiting subcutaneous Raji-cell tumor growth in nude mice (FIGs. 16-18). Tumor growth was observed in the PBS control group beginning at 4 weeks. However, no tumor growth was observed in groups treated with Rituxan® or 2H7.v16 at 5 mg/kg or 0.5 mg/kg for the 8-week duration of the study. In the low-dose 0.05 mg/kg treatment groups, tumors were observed in one animal in the 2H7 group and in one animal in the Rituxan® group (FIG. 18).

Example 15**Cloning of Cynomolgus monkey CD20 and antibody binding**

The CD20 DNA sequence for cynomolgus monkey (*Macaca fascicularis*) was determined upon the isolation of cDNA encoding CD20 from a cynomolgus spleen cDNA library. A SUPERSCRIPT™ Plasmid System for cDNA Synthesis and Plasmid Cloning (Cat#18248-013, Invitrogen, Carlsbad, CA) was used with slight modifications to construct the library. The cDNA library was ligated into a pRK5E vector using restriction sites Xho I-and Not I. mRNA was isolated from spleen tissue ((California Regional Research Primate Center, Davis, CA). Primers to amplify cDNA encoding CD20 were designed based on non-coding sequences of human CD20. N-terminal region primer 5'-AGTTTGAGAGCAAAATG-3' and C-terminal region primer 5'-AAGCTATGAACACTAATG-3' were used to clone by polymerase chain reaction (PCR) the cDNA encoding cynomolgus monkey CD20. The PCR reaction was carried out using Platinum Taq DNA Polymerase High Fidelity according to the manufacturers recommendation (Gibco, Rockville, MD). The PCR product was subcloned into pCR®2.1-TOPO® Vector (Invitrogen) and transformed into XL-1 blue *E. coli* (Stratagene, La Jolla, CA). Plasmid DNA containing ligated PCR products was isolated from individual clones and sequenced.

The amino acid sequence for cynomolgus monkey CD20 is shown in Figure 19. Figure 20 shows a comparison of cynomolgus and human CD20. The cynomolgus monkey CD20 is 97.3% similar to human

5 CD20 with 8 differences. The extracellular domain contains one change at V157A, while the remaining 7 residues can be found in the cytoplasmic or transmembrane regions.

Antibodies directed against human CD20 were assayed for the ability to bind and displace FITC-conjugated murine 2H7 binding to cynomolgus monkey cells expressing CD20. Twenty milliliters of blood were drawn from 2 cynomolgus monkeys (California Regional Research Primate Center, Davis, CA) into 10 sodium heparin and shipped directly to Genentech Inc.. On the same day, the blood samples were pooled and diluted 1:1 by the addition of 40 ml of phosphate buffered saline (PBS). 20 ml of diluted blood was layered on 4 x 20 ml of Ficoll-Paque™Plus (Amersham Biosciences, Uppsala, Sweden) in 50 ml conical tubes (Cat#352098, Falcon, Franklin Lakes, NJ) and centrifuged at 1300 rpm for 30 minutes R.T. in a Sorval 7 centrifuge. (Dupont, Newtown, CT). The PBMC layer was isolated and washed in PBS. Red blood cells 15 were lysed in a 0.2% NaCl solution, restored to isotonicity with an equivalent volume of a 1.6% NaCl solution, and centrifuged for 10 minutes at 1000 RPM. The PBMC pellet was resuspended in RPMI 1640 (Gibco, Rockville, MD) containing 5% fetal bovine serum (FBS) and dispensed into a 10 cm tissue culture dish for 1 hour at 37° C. The non-adherent B and T cell populations were removed by aspiration, 20 centrifuged and counted. A total of  $2.4 \times 10^7$  cells were recovered. The resuspended PBMC were distributed into twenty 12 x 75 mm culture tubes (Cat#352053, Falcon), with each tube containing  $1 \times 10^6$  cells in a volume of 0.25 ml. Tubes were divided into four sets of five tubes. To each set was added either media 25 (RPMI1640, 5% FBS), titrated amounts of control human IgG<sub>1</sub> antibody, Rituxan®, 2H7.v16, or 2H7.v31, The final concentration of each antibody was 30, 10, 3.3 and 1.1 nM. In addition, each tube also received 20  $\mu$ l of Fluorescein Isothiocyanate (FITC)-conjugated anti-human CD20 (Cat#555622, BD Biosciences, San Diego, CA). The cells were gently mixed, incubated for 1 hour on ice and then washed twice in cold PBS. The cell surface staining was analyzed on a Epic XL-MCL (Coulter, Miami, FL), the geometric means derived, plotted (KaleidaGraph™, Synergy Software, Reading, PA) versus antibody concentrations.

Data in Figure 21 showed that 2H7 v.16 and 2H7 v.31 competitively displaced FITC-murine 2H7 binding to cynomolgus monkey cells. Furthermore, Rituxan® also displaced FITC-murine 2H7 binding thus 30 demonstrating that both 2H7 and Rituxan® bind to an overlapping epitope on CD20. In addition, the data show that the IC<sub>50</sub> value for 2H7 v.16, 2H7 v.31 and Rituxan are similar and fall in the 4-6 nM range.

#### Example 16

##### **Phase I/II study of rhuMAb 2H7 (2H7.v16) in moderate to severe rheumatoid arthritis**

35

##### **Protocol Synopsis**

A randomized, placebo-controlled, multicenter, blinded phase I/II study of the safety of escalating doses of PRO70769 (rhuMAb 2H7) in subjects with moderate to severe rheumatoid arthritis receiving stable doses of concomitant methotrexate.

40

##### **Objectives**

The primary objective of this study is to evaluate the safety and tolerability of escalating intravenous (IV) doses of PRO70769 (rhuMAb 2H7) in subjects with moderate to sever rheumatoid arthritis (RA).

5      **Study Design**

This is a randomized, placebo-controlled, multicenter, blinded Phase I/II, investigator- and subject-blinded study of the safety of escalating doses of PRO70769 in combination with MTX in subjects with moderate to severe RA. The study consists of a dose escalation phase and a second phase with enrollment of a larger number of subjects. The Sponsor will remain unblended to treatment assignment.

10     Subjects with moderate to severe RA who have failed one to five disease-modifying antirheumatic drugs or biologics who currently have unsatisfactory clinical responses to treatment with MTX will be enrolled.

15     Subjects will be required to receive MTX in the range of 10-25 mg weekly for at least 12 weeks prior to study entry and to be on a stable dose for at least 4 weeks before receiving their initial dose of study drug (PRO70769 or placebo). Subjects may also receive stable doses of oral corticosteroids (up to 10 mg daily or prednisone equivalent) and stable doses of nonsteroidal anti-inflammatory drugs (NSAIDs).

Subjects will receive two IV infusions of PRO70769 or placebo equivalent at the indicated dose on Days 1 and 15 according to the following dose escalation plan (see Figure 22).

20     Dose escalation will occur according to specific criteria (see Dose Escalation Rules) and after review of safety data by an internal safety data review committee and assessment of acute toxicity 72 hours following the second infusion in the last subject treated in each cohort. After the dose escalation phase, 40 additional subjects (32 active and 8 placebo) will be randomized to each of the following dose levels: 2x50 mg, 2x200 mg, 2x500 mg, and 2x1000 mg, if the dose levels have been demonstrated to be tolerable during the dose escalation phase. Approximately 205 subjects will be enrolled in the study.

25     B-cell counts will be obtained and recorded (for study assessments, see Section 4.5 and Appendix A-1). B-cell counts will be evaluated using flow cytometry in a 48-week follow-up period beyond the 6-month efficacy evaluation. B-cell depletion will not be considered a dose-limiting toxicity (DLC), but rather the expected pharmacodynamic outcome of PRO70769 treatment.

30     In an optional substudy, blood for serum and RNA analyses, as well as urine samples will be obtained from subjects at various timepoints (see Section 3.3.3). These samples may be used to identify biomarkers that may be predictive of response to PRO70769 treatment in subjects with moderate to severe RA.

**Outcome Measures**

35     The primary outcome measure for this study is the safety and tolerability of PRO70769 in subjects with moderate to severe RA.

**Study Treatment**

Cohorts of subjects will receive two IV infusions of PRO70769 or placebo equivalent at the indicated dose 40 on Days 1 and 15 according to the following escalation plan:

- 10 mg PRO70769 or placebo equivalent: 4 subjects active drug, 1 control
- 50 mg PRO70769 or placebo equivalent: 8 subjects active drug, 2 control
- 200 mg PRO70769 or placebo equivalent: 8 subjects active drug, 2 control
- 500 mg PRO70769 or placebo equivalent: 8 subjects active drug, 2 control
- 1000 mg PRO70769 or placebo equivalent: 8 subjects active drug, 2 control

5    **Efficacy**

The efficacy of PRO70769 will be measured by ACR responses. The percentage of subjects who achieve an ACR20, ACR50, and ACR70 response will be summarized by treatment group and 95% confidence intervals will be generated for each group. The components of these response and their change from baseline will be summarized by treatment and visit.

10

**Conclusion**

The data above demonstrated the success in producing humanized CD20 binding antibodies, in particular humanized 2H7 antibody variants, that maintained and even enhanced their biological properties. The humanized 2H7 antibodies of the invention bound to CD20 at affinities similar to the murine donor and chimeric 2H7 antibodies and were effective at B cell killing in a primate, leading to B cell depletion. Certain variants showed enhanced ADCC over a chimeric anti-CD20 antibody currently used to treat NHL, favoring the use of lower doses of the therapeutic antibody in patients. Additional, whereas it may be necessary for a chimeric antibody that has murine FR residues to be administered at a dose effective to achieve complete B cell depletion to obviate an antibody response against it, the present humanized antibodies can be administered at dosages that achieve partial or complete B cell depletion, and for different durations of time, as desired for the particular disease and patient. In addition, these antibodies demonstrated stability in solution. These properties of the humanized 2H7 antibodies make them ideal for use as immunotherapeutic agent in the treatment of CD20 positive cancers and autoimmune diseases; these antibodies are not expected to be immunogenic or will at least be less immunogenic than fully murine or chimeric anti-CD20 antibodies in human patients.

**References**

References cited within this application, including patents, published applications and other publications, are hereby incorporated by reference.

The practice of the present invention will employ, unless otherwise indicated, conventional techniques of molecular biology and the like, which are within the skill of the art. Such techniques are explained fully in the literature. See e.g., Molecular Cloning: A Laboratory Manual (J. Sambrook *et al.*, Cold Spring Harbor Laboratory, Cold Spring Harbor, N.Y., 1989); Current Protocols in Molecular Biology (F. Ausubel *et al.*, eds., 1987 updated); Essential Molecular Biology (T. Brown ed., IRL Press 1991); Gene Expression Technology (Goeddel ed., Academic Press 1991); Methods for Cloning and Analysis of Eukaryotic Genes (A. Bothwell *et al.* eds., Bartlett Publ. 1990); Gene Transfer and Expression (M. Kriegler, Stockton Press 1990); Recombinant DNA Methodology II (R. Wu *et al.* eds., Academic Press 1995); PCR: A Practical Approach (M. McPherson *et al.*, IRL Press at Oxford University Press 1991); Oligonucleotide Synthesis (M. Gait ed., 1984); Cell Culture for Biochemists (R. Adams ed., Elsevier Science Publishers 1990); Gene Transfer Vectors for Mammalian Cells (J. Miller & M. Calos eds., 1987); Mammalian Cell Biotechnology (M. Butler ed., 1991); Animal Cell Culture (J. Pollard *et al.* eds., Humana Press 1990); Culture of Animal Cells, 2<sup>nd</sup> Ed. (R. Freshney *et al.* eds., Alan R. Liss 1987); Flow Cytometry and Sorting (M. Melamed *et al.* eds., Wiley-Liss 1990); the series Methods in Enzymology (Academic Press, Inc.); Wirth M. and Hauser H. (1993); Immunochemistry in Practice, 3rd edition, A. Johnstone & R. Thorpe, Blackwell Science, Cambridge, MA, 1996; Techniques in Immunocytochemistry, (G. Bullock & P. Petrusz eds.,

- 5 Academic Press 1982, 1983, 1985, 1989); Handbook of Experimental Immunology, (D. Weir & C. Blackwell, eds.); Current Protocols in Immunology (J. Coligan et al. eds. 1991); Immunoassay (E. P. Diamandis & T.K. Christopoulos, eds., Academic Press, Inc., 1996); Goding (1986) Monoclonal Antibodies: Principles and Practice (2d ed) Academic Press, New York; Ed Harlow and David Lane, Antibodies A laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York, 1988; Antibody
- 10 Engineering, 2<sup>nd</sup> edition (C. Borrebaeck, ed., Oxford University Press, 1995); and the series Annual Review of Immunology; the series Advances in Immunology.

## 5 WHAT IS CLAIMED IS:

1. A humanized antibody that binds human CD20, or an antigen-binding fragment thereof, wherein the antibody is effective to deplete primate B cells in vivo, the antibody comprising in the H chain Variable region ( $V_H$ ) at least a CDR3 sequence of SEQ ID NO. 12 from an anti-human CD20 antibody and substantially the human consensus framework (FR) residues of human heavy chain subgroup III ( $V_{H\text{III}}$ ).
- 10 2. The antibody of claim 1, further comprising the H chain CDR1 sequence of SEQ ID NO. 10 and CDR2 sequence of SEQ ID NO. 11.
3. The antibody of claim 2, further comprising the L chain CDR1 sequence of SEQ ID NO. 4, CDR2 sequence of SEQ ID NO. 5, CDR3 sequence of SEQ ID NO. 6 and substantially the human consensus framework (FR) residues of human light chain  $\kappa$  subgroup I ( $V_{\kappa\text{I}}$ ).
- 15 4. The antibody of the preceding claims, comprising the  $V_H$  sequence of SEQ ID NO. 8 (v16, as shown in FIG. 1B).
5. The antibody of claim 4, further comprising the  $V_L$  sequence of SEQ ID NO. 2 (v16, as shown in FIG. 1A).
- 20 6. The antibody of claim 3, wherein the  $V_H$  region is joined to a human IgG chain constant region.
7. The antibody of claim 6, wherein the human IgG is IgG1 or IgG3.
8. The antibody of claim 1, wherein the antibody is 2H7.v16 having the light and heavy chain amino acid sequence of SEQ ID NO. 21 and 22, respectively, [as shown in FIG. 6 and FIG. 7]
- 25 9. The antibody of claim 1, wherein the antibody is 2H7.v31 having the light and heavy chain amino acid sequence of SEQ ID NO. 2 and 23, respectively, [as shown in FIG. 6 and FIG. 8].
10. The antibody of claim 5, but with the amino acid substitutions of D56A and N100A in the H chain and S92A in the L chain. [v.96]
11. The antibody of any of the preceding claims, further comprising at least one amino acid substitution in the Fc region that improves ADCC and/or CDC activity.
- 30 12. The antibody of claim 11, wherein the amino acid substitutions are S298A/E333A/K334A.
13. The antibody of claim 12, wherein the antibody is 2H7.v31 having the heavy chain amino acid sequence of SEQ ID NO. 23 [as shown in FIG. 8].
14. The antibody of any of claims 1-10, further comprising at least one amino acid substitution in the Fc region that decreases CDC activity.
- 35 15. The antibody of any of claim 14, comprising at least the substitution K322A.
16. The antibody of claim 1-10 wherein the antibody is 2H7.v114 or 2H7.v115 having at least 10-fold improved ADCC activity as compared to Rituxan.
17. The antibody of claim 1 wherein the primate B cells are from human and Cynomolgus monkey.
18. The antibody of any of the preceding claims conjugated to a cytotoxic agent.
- 40 19. The antibody of claim 18 wherein the cytotoxic agent is a radioactive isotope or a toxin.
20. The antibody of any of the preceding claims, which antibody is produced in CHO cells.
21. An isolated nucleic acid that encodes the antibody of any one of the preceding claims.
22. An expression vector encoding the antibody of any of the preceding claims.
23. A host cell comprising a nucleic acid of claim 21.
- 45 24. The host cell of claim 23 that produces the antibody of any one of preceding claims.

- 5        25. The host cell of claim 24 which is a CHO cell.
26. A method of producing the antibody of any one of the preceding claims, comprising culturing the cell that produces the antibody of claim 24 and recovering the antibody from the cell culture.
27. A composition comprising the antibody of claim 1 and a carrier.
28. The composition of claim 27 wherein the antibody is 2H7.v16 and the carrier is a pharmaceutically acceptable carrier.
- 10      29. An article of manufacture comprising a container and a composition contained therein, wherein the composition comprises an antibody of any of the preceding claims.
30. The article of manufacture of claim 29, further comprising a package insert indicating that the composition can be used to treat non-Hodgkin's lymphoma.
- 15      31. A method of inducing apoptosis in B cells *in vivo*, comprising contacting B cells with the antibody of any of the preceding claims, thereby killing the B cells.
32. A method of treating a CD20 positive cancer, comprising administering to a patient suffering from the cancer, a therapeutically effective amount of the humanized CD20 binding antibody of any of the preceding claims.
- 20      33. The method of claim 32 wherein the CD20 positive cancer is a B cell lymphoma or leukemia.
34. The method of claim 33 wherein CD20 positive cancer is non-Hodgkin's lymphoma (NHL) or lymphocyte predominant Hodgkin's disease (LPHD).
35. The method of claim 32 wherein the cancer is chronic lymphocytic leukemia or SLL.
36. The method of claims 34 or 35 wherein the antibody is selected from the group consisting of 2H7.v16, v31.v96, v114, v115 having the respective amino acid sequences as shown in the figures and tables.
- 25      37. The method of claim 34 or 35 wherein the antibody is 2H7.v16 having the light and heavy chain amino acid sequence of SEQ ID NO. 21 and 22, respectively, as shown in FIG. 6 and FIG. 7.
38. The method of claim 33, wherein the antibody is administered at a dosage range of about 275-375mg/m<sup>2</sup>.
- 30      39. The method of claim 32, further comprising administering to the patient at least one chemotherapeutic agent.
40. The method of claim 39, wherein the cancer is non-Hodgkin's lymphoma (NHL) and the chemotherapeutic agent is selected from the group consisting of doxorubicin, cyclophosphamide, vincristine and prednisolone.
- 35      41. A method of treating an autoimmune disease, comprising administering to a patient suffering from the autoimmune disease, a therapeutically effective amount of the humanized CD20 binding antibody of any one of the preceding claims.
42. The method of claim 41, wherein the autoimmune disease is selected from the group consisting of rheumatoid arthritis, juvenile rheumatoid arthritis, systemic lupus erythematosus (SLE), Wegener's disease, inflammatory bowel disease, idiopathic thrombocytopenic purpura (ITP), thrombotic thrombocytopenic purpura (TTP), autoimmune thrombocytopenia, multiple sclerosis, psoriasis, IgA nephropathy, IgM polyneuropathies, myasthenia gravis, vasculitis, diabetes mellitus, Reynaud's syndrome, Sjorgen's syndrome and glomerulonephritis.

- 5        43. The method of claim 42, wherein the autoimmune disease is rheumatoid arthritis.
44. The method of claim 43, further comprising administering to the patient a second therapeutic agent.
45. The method of claim 44, wherein the second therapeutic agent is an immunosuppressive agent.
46. The method of claim 45, wherein the immunosuppressive agent is methotrexate.
47. A method of treating an autoimmune disease selected from the group consisting of
- 10      Dermatomyositis, Wegner's granulomatosis, ANCA (included under vasculitis), Aplastic anemia, Autoimmune hemolytic anemia (AIHA), factor VIII deficiency, hemophilia A, Autoimmune neutropenia, Castleman's syndrome, Goodpasture's syndrome, solid organ transplant rejection, graft versus host disease (GVHD), IgM mediated, thrombotic thrombocytopenic purpura (TTP), Hashimoto's Thyroiditis, autoimmune hepatitis, lymphoid interstitial pneumonitis (HIV), bronchiolitis obliterans (non-transplant) vs.
- 15      NSIP, Guillain-Barre Syndrome, large vessel vasculitis, giant cell (Takayasu's) arteritis, medium vessel vasculitis, Kawasaki's Disease, and polyarteritis nodosa, comprising administering to a patient suffering from the disease, a therapeutically effective amount of a CD20 binding antibody or functional fragment theréof.
48. The method of claim 47 wherein the CD20 binding antibody is Rituxan®.
- 20      49. An isolated nucleic acid comprising the nucleotide sequence of SEQ ID NO.: \_ of the Cynomolgus monkey CD20 (shown in FIG. 19), or a degenerate variant of this sequence.
50. An isolated nucleic acid comprising a sequence that encodes a polypeptide with the amino acid sequence of SEQ ID NO. \_ (shown FIG. 20), or SEQ ID NO. \_ (FIG. 20) with conservative amino acid substitutions.
- 25      51. A vector comprising the nucleic acid of claim 50.
52. The vector of claim 51 which is an expression vector comprising the nucleic acid of claim 49 operably linked to an expression control sequence.
53. A host cell comprising the nucleic acid of claim 50.
54. An isolated polypeptide comprising the amino acid sequence [SEQ ID NO. \_ ; FIG. 20] of the
- 30      Cynomolgus monkey CD20.
55. A liquid formulation comprising a humanized 2H7 antibody at 20mg/mL, 10mM histidine sulfate at pH5.8, 60mg/ml sucrose, 0.2 mg/ml polysorbate 20.

**FIG. 1A**  
 Sequence alignment of variable light-chain domain

	FR1	CDR1	
2H7	QIVLSQSPAILSASPGEKVTMTC * *** ** * *** *	[RASSSVS-YMH]	WYQQKWP
hu2H7.v16	DIQMTQSPSSLSASVGDRVTITC	[RASSSVS-YMH]	WYQQKWP * * * **
hum kI	DIQMTQSPSSLSASVGDRVTITC	[RASQSIISNYLA]	WYQQKWP
	FR2	CDR2	FR3
2H7	GSSPKPWIY ** *	[APSNLAS]	GVPARFSGSGSGTYSLTISRVEA * *** ****
hu2H7.v16	GKAPKPLIY *	[APSNLAS]	GVPSRFSGSGSGTDFTLTISLQP * * * *
hum kI	GKAPKLLIY	[AASSLES]	GVPSRFSGSGSGTDFTLTISLQP
	CDR3	FR4	
2H7	EDAATYYC *	[QQWSFNPPPT]	FGAGTKLELKR * * *
hu2H7.v16	EDFATYYC *****	[QQWSFNPPPT]	FGQGTKVEIKR
hum kI	EDFATYYC	[QQYNNSLPWT]	FGQGTKVEIKR

**FIG. 1B**  
Sequence alignment of variable heavy-chain domain

	FR1	CDR1	
2H7	QAYLQQSGAELVRPGASVKMSCKAS *** *** * * * *** *	[GYTFTSYNMH]	WVKQT * *
hu2H7.v16	EVQLVESGGGLVQPGGSLRLSCAAS	[GYTFTSYNMH]	WVRQA
hum III	EVQLVESGGGLVQPGGSLRLSCAAS	[GFTFSSYAMS]	WVRQA
	FR2	CDR2	FR3
2H7	PRQGLEWIG ** *	[AIYPNGDTSYNQKFKG]	KATLTVDKSSSTAYM * * * * * *
hu2H7.v16	PGKGLEWVG * * * * * * * *	[AIYPNGDTSYNQKFKG]	RFTISVDKSKNTLYL * *
hum III	PGKGLEWVA	[VISGDGGSTYYADSVKG]	RFTISRDNSKNTLYL
	abc	CDR3	FR4
2H7	QLSsltSEDSAVYFCAR ** ** * *	[VVYYSN SYWYFDV]	WGTGTTVTVSS * *
hu2H7.v16	QMNSLRAEDTAVYYCAR	[VVYYSN SYWYFDV]	WGQGTLVTVSS ***** *** *
hum III	QMNSLRAEDTAVYYCAR	[GRVGYSLY---DY]	WGQGTLVTVSS

**FIG. 2-1**  
**PVX4**

1 GAATTCAACT TCTCCAACT TTGGATTAAGG AAATACAGAC ATGAAAAATC TCATTGCTGA GTTGTATT ATT AAGCTTGCCC AAAAGAAGA AGAGTCGAAT  
 CTTAAGTGA AGAGGATGA AACCTTCC TTATGTCG TACTTTTAG AGTAACACT CAACATAAA TTTCGACGGG TTTCATCTCT TCTCAGCTTA

101 GAACTGTGG CGCAGGTAGA AGCTTGGAG ATTATCGTCA CTGCAATGCT TCGCAATATG GCGCAAAATG ACCACAGGG GTTGATTGAT CAGGTAGGG  
 CTTGACAC GCGTCCATCT TCGRAACTC TAATAGCTG GACCTTACG AGCGTATAC CGCGTTTAC TGTTCTGC CAACAACTA GTCCCATCTCC

201 GGGCGTGTAA CGAGGTGCA CCCGATGCC GCATTCCTGA CGACGATAGS GAGCTCTGC GGCGATTAGT AAAGAGTTA TTGAGGATC CTCGTCAGTA  
 CCCGGACAT GCTCCATTTC GGGCTACGT CGTAAGGACT GTGTGTATGC CTCGAGACG CGCTAATGCA TTTCCTCAAT AACTCGTAG GAGCACTAT

301 AAAGTTAAT CTTTCACAA GCTTCATTA AGTTGTAGC GCCGAGACTT ATAGTGCTT TGTGTATT TTTCATGTA TTGTTAACTA GAATTGAGC  
 TTTCATTA GAAAGTTG CGACGATTT TCAACAGTC CGGGCTCTGAA TATCGCGAA ACAGAAATAA AAATTCAT AACATGAT CTTAAGTCTG

401 TCGGTACCCG GGGATCCTCT AGAGGTGAG GTGATTAT GAAAAGAAT ATCGGATTTC TTCTTGATC TATGTTGTTT TTTCATATTG CTACAAACGC  
 AGCGATGGC CCCTTACACT CACTAAATA CTTCCTTAA TAGCGTAAG AGAACCTAG ATACAGCAAA AGAGATAAC GATGTTGCG  
 1 M K N I A F L L A S M P V F S I A T N A

501 GTACCGTGTAT ATCCAGATGA CCCAGTCCC GAGCTCCCTG TCGCCCTCTG TGGCGATAG GTTGTCAATC ACCTTCAGAG CCAGTCAGAG CGTGTGACT  
 CATGGACTA TAGGTCTACT CGGTCTAGG CTCGAGGGAC AGCGGAGAC ACCCGTATC CGACTGGTAG TGGAGCTTC GGTCAGTCTC GCACAGCTCA  
 22 Y A D I Q M T Q S P S L S A S V G D R V T I T C R A S Q S V S T

601 AGCTCTATA GCTATATGCA CTGGTATCAA CAGAACCCG GAAAAGCTC GAAACTACTG ATTACTATG CTAGAACCT CGAGTCTGGA GTCCCTTC  
 TCGAGAATAT CGATATAGT GACCATAGTT GTCTCTGCTC CTTCCTCAGG  
 55 S S Y S Y M H W Y Q Q K P G K A P K L L I Y Y A S N L E S G ,Y P S R

701 GCTTCTCTGG ATCCGGTCT GGGACGGATT TCACCTGAC CATCAGGAGT CTGCAAGGAAAGACTCGC AACTTATTAC TGTCACACT  
 TCGAGGACCC TAGGCTTAAA CCTCTGCTTA AGTGGAGCTG GTAGTCCTCA GACGTGGTC TTCTGAAAGC TTGATAATG ACAGTGTGA GAACCCATA  
 89 F S G S G S G T D F T L T I S S L ·Q ·P E D F A T Y Y C Q H S S W G I

801 TCCGGCACA TTGGACAGG GTACCAAGGT GGAGATCAA CGAACCTGG CTGCAACATC TGTCCTOATC TTCCGGCAT CTGATGAGCA GTTGAATCT  
 AGGGCGTGT AACCTCTTC CATTCTTCCA CCTCTAGTT GCTTGACCC GACGTGGTAG ACAGHAGTTAAGGGGGTA GACTACTGT CAACTTGA  
 122 P R T F G Q G T K V E I K R T V A A P S V F I F P P S D E Q L K S

901 GGAACCTGCTT CCTGCTTAAT AACTCTATC CGAACCTGG CAAGTACAG TGGAAGTTG ATAAGCCCT CCAATCGGGT AACCTCCCG  
 CCTTGACGAA GACACACAC GGACGACTTA TIGAAGATAG GGTCCTCTCG GTTGTCTCTC ACCTCCTAACCC TATTCGGGA GTTGTGCTTA TTGAGGGTCC  
 155 G T A S V V C L L N N F Y P R E A K V Q W K V D N A L Q S G N S Q E

1001 AGAGTGTCA AGAGGAGAC AGCAAGGACA GCACCTACAG CCTCAGCAGC ACCCTGACGC TGAGCAAGC AGACTACGAG AAACACAAAG TCTACGGCTG  
 TCTCACAGTG TCTCGTCTCTG TCGTGTCTGT CGTGGATCTC GGAGTCCTG ACTCGTTGCTC TTGTGTTTC AGATGCGCAC

189 S V T E Q D S K D S - T Y S L S S T L T L S K A D Y E K H K V Y A C

FIG. 2-2

PK4

1101 CGAAGTCACC CATCGGGCC TGAGCTGCC CCTCACAAAG AGCTCAAC GGGGAGGTG TTAAGCTGAT CCTCTACGCC GGAGCGATCG TGGCCCTAGT  
 GCTTCAGTGG GTAGTCCCAG ACTCGAGGG CGAGTGTTC TCGAAGTTGT CCTCCTCTCAC AATTGACTA GGAGATGCC CCGTGCATGC ACCGGGATCA  
 222 E V T H Q G L S S P V T K S F N R G E C O  
  
 1201 ACGGAAGTTC ACGTAAAAG GGTATCTAGA CGTGTAGGTG ATTATGATAA AAGAATATC GCATTTC TCAGATCTAT TTGATCTAT GTTCGTTTT TCTATTGCTA  
 TCGTTCAAG TGCATTTC CCATAGATCT CCAACTCCAC TAAATACTT TTCTCTATAG CGTAAGAAG AACTAGATA CAAGCAAAA AGATAACGAT  
 1 M K K N I A F L L A S M F V F S I A T  
  
 1301 CAAACGGCTA CGCTGAGGT CAGGTGGTGG AGCTGGCGG TGGCTGTGG CAGCCAGGG GCTCACTCCG TTGCTCTGT GCACTCTTG GCTACACCTT  
 GTTGGCTCAT GCGACTCCAA GTGACCAAC TCAAGCCGC ACCGGACAC GTCGGTCCCC CGAGTGGGG AAACAGGACA CGTGAAGAC CGATGGAA  
 20 N A Y A E V Q L V E S G G G L V Q P G G S L R L S C A A S G Y T F  
  
 1401 CACCGAATAT ATCATCCACT GGGTCCGTC GGCCCCGGGT AAGGGCTGG ATGGGTGTC ATCGATTAA CCTGACTACG ACATCACGAA CTATAACAG  
 GTGGCTTATA TAGTAGGTGA CCCAGGAET CGGGGCCCA TTCCGGACC TTACCCAAAG TAGCTAATAA GGACTGATGC TGATGTGCTI GATATTGGTC  
 53 T E Y I I H W V R Q A P G K G L E W V A - S I N P D Y D I T N Y N Q  
  
 1501 CGCTTCAGG GCCGTTTAC TATAAGTCGC GACGATTCCA AAAACACATT ATACCTGGAG ATGAAACGCC TGCCTGCTGA GGACACTGCC GTCTTATTAT  
 GCGGAAGTTC CGGCAAAGTC ATATTAGCG CTGCTTAAGT TTGCTGTAA TATGGACCTG TACTTGTGG AGCGCAACT CCTGTCAGGG CAGATAATAA  
 86 R F K G R F T I S R D D S K N T L Y L Q M N S L R A E D T A V Y Y C  
  
 1601 GTGCTCGATG GATCAGCGAT TTCTTCGACT ACTGGGGTCA AGGAACCTTG GTCACCGCTCT CCTCGGCC CACRAAGGG CCATCGGTCT TCCCCCTGGC  
 CACGAGCTAC CTAGTCGCTA AGAAAGCTGA TGACCCAGT TCGTGGAC CAGTGGCGAA GGAGCGGGAG GTGGTCCCG GTIAGCCAGA AGGGGGACCG  
 120 A R W I S D F F D Y W G Q G T L V T V S S A S T K G P S V F P L A  
  
 1701 ACCCTCCCTCC AAGAGCACT CTGGGGCAC AGGGCCCTGG TCAAGGACTA CTTCCCCAA CGGGTACGG TGTCGTGGAA CTCAGGGGCC  
 TGGAGGGGG TTCTCGTGA GACCCCCGGT TGCGGGAC CGAACGGAC AGTTCCTGAT GAAGGGGGT GGCCACCTGC ACAGCACCTI GAGTCGGGG  
 153 P S S K S T S G G T A A L G C L V K D Y F P E P V T V S W N S G A  
  
 1801 CTGACCAAGG GCGTGCACAC CTTCCCCGGT GTCTCTACAGT CCTCAGGACT CTACTCCCTC AGCAGCGGG TGACCGTGG CTCACAGGC TTGGGCACCC  
 GACTGGTGC CGCACCTTG GAGGGCCCA CAGGATCTCA GGAGTCCTGA TCGTGTGG ACTCGGACG GAGTCCTGC AACCCGGGG  
 186 L T S G V H T F P A V L Q S S G L Y S L S S V V T V P S S S L G T Q  
  
 1901 AGACCTACAT CTGCAACGTC CGACAGCATC AATCACAAAG CCAGCAACAC CAAGGTGGAC AGAAAGTGC AGCCAAATC TTGTGACAA ACTCACAT GACCAACGCA  
 TCTGGATGTA GACCTTGAC TTAGTGTG TGTTCCACCTG TCTCTTCAAC TCGGGTTAG AACACTGTT TGTGTGTGA CTGGGTGGCTGT  
 220 T Y I C N V N H K P S N T K V D K K V E P K S C D K T H T O  
  
 2001 TGCACCAAGT CGTCCATTIC CGACAGCATC ATGCGTCACT GCTAGGCGGG CCCTATACT TGTCGTGCTC CCCCGCTTC GTCGGGGTC  
 ACGTGGTCACT ACCAGGTGAG GCTGTCGTAG CGGTCACTGA TACCGGACGA CGATCGGGCC GGGATATGA ACAGCGSAG GGGGGTACG AAGGCCACG  
  
 2101 ATGGAGCGGG GCCACCTCGA CCTGAATGGA AGCCGGCGGC ACCTCGCTAA CGGATTACCC ACTCCAAAC TCGAGGCGAA TCAATTCTTG CGAGAAACTG  
 TACCTCGCC CGTGGACTT GGACTTACT TCGGCGCCG TGGAGGCACT GGCTAAGTGG TGAGGTGTT AACCTGGTT AGTAAAC GCCTCTTGAC  
  
 2201 TGAATGGCA ACCAACCTT TGGCAGANCA TATCCATCGC GTCCGCCATC TCCAGGACCG GCACGCCGGG CATCTCGGC AGCGTGGGT CTCGGCCACG  
 ACTACCGT TTGGTGGAA ACCGTCGTGT ATAGGTAGCG CAGGCGGTAG AGGTAGCGTGG CGTACGGCGC GTAGAGCGC TCGAAACCA GAACCGGTGAC

FIG. 2-3  
PVX4

2301 GTCGCCATG ATCGTGTCC TGTCTGGAG GACCCGGTA GGCTGGGG GTGCTTAC CGATAATCAC ATGAACTAC CGATAAGCGA GCGAACGTGA  
CCACGGTAC TAGCAGGAG ACAGCAACTC CTGGCCCAT CCGACGCC CAAAGGAATG ACCATGTC TTACTAGTC GCTATGGCT CGCTTGACT

2401 AGGGACTGCT GCTGAAAAAC GTCGGGACC TGAGCACA CATEATGGT CTTCGGTT CGTGTTCGT AAAGTCTGA AACGGGAAG TGCGCCCT  
TGCCTGACGA CGAGTGTG CAGAGCTGG ACTCGTTT GTACTACCA GAAGCCLAAG GCACAAAGCA TTTCGACT TTGCGCTTC AGTGGGGA

2501 GCACCATTAAT GTTCGGATC TGCATGGAG GATGCTGGT GTTACCTGT GEAACACTA CATCTATT AACGAAGGC TGGCATGAC CCTGAGTGT  
CGGGTAACTA CAAGGCTTAG ACCTAGGTC CTAAGAAC CGATGGACA CCTTGTGGAT GTAGACATA TTGCTTGGC ACCGTAATG GGACTCACTA

2601 TTTCCTCTGG TCCCCTGGCA TCCATACCGC CAGTGTATA CCCTCACAAC GTTCCAGTAA CGGGCATGT TCACTATCG TAACCGTAT CGTACGATC  
AAAAGAGACC AGGGGGCGT AGGTATGGCG GTCAACAAAT GGGAGTGTG CAGGTCTT GCCCGTACA ATAGTAGTC ATTGGCATA GCACCTGTAG

2701 CTCTCTCGTT TCATCGGTAT CATTACCCC ATGACAGAA ATTCCCCCTT ACACGGGGC ATCTAGTGC CAACAGGAA AAACCGCCC TAAACATGGC  
GAGAGGCAA AGTAGCCATA GTAAACCAAGA ATGATGGGG TACTGTCTT TAACGGGAA TGTGCTCCG TACTGTACTG GTTGTCTTT TTGGGGGG AATTTGACCG

2801 CGCGTTTATC AGAAGCCAGA CATTAAAGCT TCTGAGAAA CTCACAGAGC TGAACAGGCA GACATCTGTG ATCGCTTCA CGACACGCT  
GGCGAAATAG TCTTGGTCT GTAAATGGCA AGACCTCTT GAGTGTCTG ACCTGCGCTT ACTGTGCTGT CTGAGACAC TTAGGAACT GTGCGTGCAG

2901 GATGAGCTTT ACCGAGGAT CGGGAAATG TAAACGTAA TATTGTTAA AAATCGCGT TAAATTGTT TAAATCGC TCAATTGTTA ACCAATAGGC  
CTACTCGAAA TGGCTGCTA GGCCCTTAAC ATTGCAATT ATTAAACAT TTAAGCGCA ATTAAAAAC AATTAGTCG AGTAAATAAT TGGTATCCG

3001 CGAAATCGGC AAAATCCCTT ATAAATCAA AGAATAGACC GAGATAGGGT TGAAGTGTG TCCAGTTGG AACAAGAGTC CACTATAAA GAACGGGAC  
GCTTGTGCC TTTTAGGGAA TATTAGTTT TCTATCTGG CTCTATCCA ACTCACAACA AGCTAAAC ACCTAAACC TTGTCTAG GTGATAATT CTGACACTG

3101 TCCBACCTCA AAGGGCGAA AACCGCTTAT CAGGGCTTG GCCACATCG TGAACTAC CCCTAAATCA GTTTTTGG GTGAGGGTC CGTAAAGCAC  
AGGTGCGATI TTCCCGCTT TGGCAGATA GTCCCGATAC CGGGTGTG ACTTGTGACT GGGATTAGT CTGTTTGTG CAGTCACAG GCATTTCGTG

3201 TAAATCGGA CCCTAAAGGG AGCCCCGAT TTAGAGCTG ACGGGGAAAG CGGGGAACG TGGCAGAAA GGAGGGAAAG AAAGGAAAG<sup>1</sup>'AGGGGGGC  
ATTAGCTT GGGATTTCCTC TGGGGCTA ATCTCGAAC TGCCCTTGC ACCGCTT CTTCCCTTC TTTCGTTTC CTCCCGCC  
3301 TAGGGCGCTG GCAAGTGTAG CGGTCAAGCT GGGCGTAACC ACCAACCC CGGGCTTAA TGGGCCGTA CAGGGCGGT CGCATCTG CCTCGCGGT  
ATCCCGGAC CGTCACATC GCGATGG CGCAGTGCAG CGCGATTTGGC GGGCGAATT AGCGGGCAT GTCCCGGCA GGCGTAGGAC GGAGCGGCA

3401 TTCGGTGTG ACGGTGAAA CCTCTGACAC ATGGAGCTCC CGAGGACGGT CAGCGCTGT CTGTAAGGG ATGCCAGGC CGTCAGGGG  
AAGCCACTAC TGCCACTTT GGAGACTGTG TACGTGAGG GCCTCTGCC GTGTGAACA GACATTGCC TACGGCCCTC GTCTGTCTGG CGAGTCCCGC

3501 CGTCAGGGG TGTTGGGG CAGGGATGAC CGGTCAAGT AGGGTAGGG GAGTGTATAC TGGCTTAATCT AGGGGGATC AGAGGAGATT  
GCAGTCCGCC ACAACGCC ACCGCCCC GTCGGTACTG GTGAGTGCAG TGGCTATGCA TCGCATATG AGCGAATTGA TACGGCGTAG TCTGTCTAA

3601 GTACTGAGG TGCACTAT GGGGTGTGAA ATACCGCACA GATGGTTAAG GAGAAATAAC CGCATCAGGC GCTCTTCCGC TTCTCGCTC ACTGACTCGC  
CATGACTCTC ACGTGGTATA CGCCACACTT TATGGCTGTG CTACGATTC CTCTTATG GCGTAGTCCG CGAGAAGGGG AAGGAGGAG TGACTGAGG

3701 TGCGCTCGT CGTTCGGCTG CGGGAGGGG TATCAGCTCA CTCAAAGGG GTAAATACGGT TATCCACAGA ATCAGGGGAT AACGCCAGGA AGAACATGTG  
ACGGCAGGCA GCAGGCCGAC GCCTGCTGCC ATAGTCGAGT GAGTTCCGC CATTATGCCA ATAGGTGTCT TTGCTCCCTA TTGCTCCCT TCTGTACAC

**FIG. 2-4**  
PVX4

3801 AGCAAAAGG CGAGGAACCC TAAAAGGCC GCGTTCCTGG CGTTTTTCCA TAGGCTCAGC CCCCTCAGC ACCATCACAA AATCGACGC  
TCGTTTCCG GTCTTTTC CCGTCTTGGC ATTTTCGG CGCAAGGACC GCAAAGGT ATCGAGGCC GCGAAAGGT AGTCAAGTCTT TTAGCTGCC  
AGTCAAGTCT CACCGCTT GGCGTGTCTT GCGGAGCTT AGTAAAGGTT TCCCGCTGG AGCTCCCTCG AGCTCCCTCC TGGCTCGACC TGTCCGCTTA  
AGTCAAGTCT CACCGCTT GGCGTGTCTT GCGGAGCTT AGTAAAGGTT TCCCGCTGG AGCTCCCTCG AGCTCCCTCC TGGCTCGACC TGTCCGCTTA  
4001 CCGGATACT GTCCGCTT CTCCGCTT CTCCGCTT AGTCAAGTCT CAGTCAAGTCTT AGTCAAGTCTT CAGTCAAGTCTT CAGTCAAGTCTT  
GGCTATGCA CGGGGAAAGGCC CTTGACCG CGAAAGGTT TCGATGCA CATCCATAGA GTCAGGCCATCAGCAATCGA CGAGGTTGCA  
4101 GGGCTGTG CACGAACCC CGGTTCAAGC CGACCGCTGC GCCTTATCCG GAACTATCG TCTTGAGTCC AACCGGTT AACAGCACT ATGCCACTG  
CCGACACAC GTGCTGGGG CGCAAGTGGG GCGAAAGGAGC CGAAATGGC CATTGATGCC AGAACTCAGG TTGCCCATT CTGCTGAA TAGGGTGA  
CGTGTGGT GACCATGTC CAAATGTC ATGCTCACAC ATGCTCAAG AACTTCACCA CGGATGATGCC TGTCTGTC TGTCTGTC  
4201 GCAGCAGGCA CTGGTAACAG GATTAGCAGA GGGAGGTATG TAGCGGGTC TACAGAGTTC TGAAGTGGT GGCTTAACAGT CGGCTAACAG  
CGTGTGGT GACCATGTC CAAATGTC ATGCTCACAC ATGCTCAAG AACTTCACCA CGGATGATGCC TGTCTGTC TGTCTGTC  
4301 TATTGGTAT CTGCGCTCTG CTGAGCCAG TTACCTCGG AAAAGAGTT GTAGCTCTT GATGGCTCTT GCTCCGGCA ACAAAACACC  
ATAAACCTATA GACGCCGAGC GACTCGCTC AAATGGAGCC TTTCCTCAAA CCATCGAGAA CTAGGCCGTT TGTTGGTGG CGACCATCGC GACCAAAAAA  
4401 TGTGGAG CAGCAGATA CGGGAGAAA AAAAGGATCT CAAAGAGTC CTTTGATCTT TTCTACGGG TCTGAGCCTC AGTGGAAACGA AACTCACGT  
ACAACAGTC GTCGTCTAAAT GCGCGTCTTT TTTCCTAGA GTTCCTCTAG GAAACTAGAA AAAGATGCCCG AGACTGCCAG TCACCTTGTCTT  
4501 TAAGGGATT TGGTCATGAG ATTATCAAA AGGATCTCA CCTAGATCTT TTAAATTAA AAATGAGTT TTAATCAAT CTAAAGTATA TATGAGTAA  
ATTCCCTAA ACCAGTACTC TAATGTTT TCCTGAGT GGATCTAGGA AAATTAAATT TTACTCTAA AATTAGTTA GATTCTATAT ATACTCTTT  
4601 CTGGTCTGA CAGTACCAAA TGCTTAATCA GTGAGGCCAC TATCTCAGGC ATCTGCTTAT TTCTGCTCATC CATACTGCC TGAATCCCC  
GAACCAAGCT GTCAATGTT AGCAATTAGT CACTCGTGG ATAGACTGCG TAGACAGATA AGCAAGTAG GTATCAACGG ACTGAGGGGC AGCACATCTA  
4701 AACTACGATA CGGGAGGGCT TACCATCTGG CCCCACTCTGCT GCAATGATAAC CGCTTACCCG GCTCCAGATT TACAGCAAT'AAACAGGCCA  
TTGATGTTAT GCCCTCCGA ATGGTAGACC GGGTCACGA CGTCTACTATG GCGCTCTGG TAGCAGTGGC CGAGGTCTAA ATAGCTGTTA TTGGTCTGGT  
4801 GCGGAAAGG CGAGGCCAG AAGTGGTCTT GCAACTTTAT CCCCACTCTGCT COAGCTTAT AATTGGTGC  
CGGCTTCCC GGCTCGCTC TTGCAAAAGCA CGGTAACGAC GTCCGTAGCA CCACAGTGG ACCAGCAAC CATACCGAG TAAGTGGAGG CCCTTGATC  
TCAATGCTACT AGGGGGTACA ACAGGTTTT TCGCCATAGC AGGAGCCAG GAGGCTAGCA ACAGTCTCA TCAACAGG TCATTCATCA AGGGTCAAT  
4901 ATAGTTGGG CAACTCCATGT TGTGCAAAA ACCGGTTAGC CAGGATGCTT GGTGCTACGC TGGCTGGTTG GTATGGCTTC ATTGAGCTCC  
TCAATGCTACT AGGGGGTACA ACAGGTTTT TCGCCATAGC AGGAGCCAG GAGGCTAGCA ACAGTCTCA TCAACAGG GTCACAAATAG TGAGTACCA  
5101 ATGECAGGAC TGCATAATTG TCTTACTGTC ATGCCATCCG TAAGATGCTT TTCTGTTGACT GGTGAGTACT CAACCAAGTC ATTCTGAGAA TATGTGATGC  
TACCGTCTG AGTATTAAG AGAATGACAG TACGGTAGGC ATTCTACCAAA AGAACACTGAA CCACTCTAA GTGGGTTGAG TAAGACTCTT ATCACATAG  
5201 GGCACCGAG TTGCTCTGC CGGGCTCAA CACGGGATAA TACGGGCAAA CAGGGGATAA TACGGGCAAA CTTTAAAGT GTCATCTTAA  
CCGCTGGCTC ACGGAAAGC GGGCCGCTT GTGCCCTTAA ATGCGGCTGT GTCATCTTAA GAAATTTCAGA CGAGTGTAA CCTTTGCAA GAAGCCCCGC

FIG. 2-5

PVX4

5301 AAAACTCTCA AGGATCTTAC CGCTGTGAG ATCCAGTTCG ATGTAACCCA CTCGTGCAAC CAACTGATCT TCAGCATCT TTACTTCAAC CAGGGTTCT  
 TTTTGAGAGT TCCTAGAATG GCGACAACTC TAGGTGAAAGC TACATTGGGT GAGGCACTGG GTTGACTAGA AGTCGTGAA ATGAAAGTG GTGCGAAAGA

5401 GGCTAGCAA AACAGGAAG GAAAATGCC GCAAAGAAC GAAATAAGGGC GACACCGAAA TGTTGAAATAC TCATACTCTT CCTTTTCAA TATTATGAA  
 CCCACTCGTT TTGTCCTTC CGTTTACGG CTATTTCCG CTGTCCTT ACAACTTATG AGPATGAGAA GGAAAAGTT ATAATAACTT

5501 GCATTATCA GGTTATGTT CTCATGAGCG GATACATATT TGAATGTTAG TAGAAATAATA ACAAAATAGG GETTCGGGC ACATTTCCC GAAAAGTGCC  
 CGTAAATAGT CCATAACA GAGTACTGC CTATGTTAA ACTTACATRA ATCTTTTAT TTGTTATCC CCAAGGGCG TGTAAGGGG CTTTTCA CGG

5601 ACCTGAGTC TAGAAACCA TTATTATCAT GACATTACCA TATAAAATA GGCGTATAC GAGGCCCTT CGCTTCAA  
 TGGACTGCAG ATCTTTGGT AATAATAGTA CTGTTATGG ATATTTAT CCGTATAGT CTCGGGAA GCAGAAGTT

FIG 3-1

P2H7.chim6.8

1 GAATTCAACT TCTCCGAACT TTGGATAAGC AAAATACAGAC ATGAAAATTC TCATTTGCTGA GTTGTATTAA AAGCTTGCCCC AAAAGAAGA AGAGTCGAAT  
CTTAAGTGA AGAGGTATGA AACCTTATCC TTATGCTCTG TACTTTTAG AGTAACTCTG TCTAGCTTA

101 GAACTGTGTG CGCAGGTGA AGCTTGGAG ATTATCGTCA CTGCAATGCT TCGCAATATG GCGAAAATG ACCAACAGCG GTTGATGAT CAGGTAGGG  
CTTGACACAC GCGTCCATCT TCGAACACCTC TAATAGCTCT GACGTAACTGA AGCGTTACG CGCGTTAAC CGCGTTAAC TGTTGTCTGC CAACTAACTA GTTCATCTCC

201 GGGCGCTGTA CGGGTAAG CCCGATGCCA GGAATTCTGA CGACGATAGC GAGGTGTGC CGACGATAGC GCGATTACG TCGTGTCTGC TGGTGTCTGC  
CCCGCGACAT GCTCCATTGCTT GGGTACGGT CGTAAGGACT GCTGCTATGC CTCGACGAC CGCTAATGCA TTCTCTCAT AACTCTGTAG GACGACTAT

301 AAAAGTTAT CTITCAACA GCTGTCAAAC ACTTGTACG GCGGAGACTT ATAGTGCTT TGTTTTATT TTAAATGTA TTGTGTACTA GAATTGAGC  
TTTCAATTA GAAAGTTGT CGACAGTATT TCAACAGTGC CGGCTCTGAA TATCGCGAA ACAAAATTA AAAATTACAT AAACATGTAT CTTAAGCTCG

401 TCGGTACCCG GGGATCCTCT AGAGGTGAG GTGATTATG AAAAGAATA TCGCAATTCT TCTGCACT ATGTTGCTT TTCTTATTGC TACAAACGCG  
AGCCATGGGC CCCTAGGAA TCTCCAACTC CAAATAATAC TTCTCTTAT AGCGTAAAGA AGAACGTAGA TACAGGCAA AAAGATAACG ATGTTTGCGC

491 M K N I A F L L A S M F V F S I A T N A

1 .

501 TAGGCTCAGA TAGTACTCTC CCAAGTCCCCG CCTATCCCTG CGCGCTCTCC TGGCGAGAG GTOACTATGA CCTGAGAGC CAGGTCTCTC GTGAGGCTATA  
ATGGGAGTCT ATCTGAG GGTCAAGGGC CGATAGGACA GGCGGAGGG ACCGGCTCTC CAGGTGATACT GGACGTTCTCG GTTCAAGAAGA CACTGATAAT

591 22 Y A Q I V L S Q S P A I L S A S P G E K V T M T C R A S S V S Y M

56 H W Y Q Q K P G S S P K P W I Y A P S N L A S G V P A R F S , G S G

601 TGCGATGGTA TCAACAGAAA CCAGGAAGCT CTCGAAACC ATGGATTAC GCTCCATCGA ACCTGGCGTC TGGAGTCCCT GCGCGCTCTC TGCGAGGCTTCT  
ACGTAACCAT AGTGTCTT GTTGTCTGAG ACTGGTACTC CATCTGTCTT GGTCTCTGAG ATGAGACTT CGAGGTAGCT TGGAGGCGAG ACCTCAGGGAA CGCGCGAGAA GAGCTAGGGC

69 S G T S Y S L T I S R V E A E D A A T Y C Q Q W S F N P P T F G

701 TTCTGGACT AGTTRACTCTC TGACCATCG CAGATGGAG GCGAGAAGCG CGCGAACTTA TTACTGTCAA CAGTGGAGCT TCAATCCGGC CACATTGGA  
AAGACCCCTGA TCAATGAG ACTGGTACTC GTCACCTCTGC CGCTCTCTGC GGCCTGTAAAT AATGACAGTT GTCAACCTCGA AGTGTGGGG ETGTAAACCT

79 S G T S Y S L T I S R V E A E D A A T Y C Q Q W S F N P P T F G

801 GCGGGACCA AGCTGGAGCT CAAACGAACT GTGGCTGGAC CATCTGTCTT CACCTCTCCG CCACCTGTAT AGCAGTTGAA ATCTGAACT GCTTCTGTG  
CGGCCGTGGT TCGACCTCGA GTTGTCTGA CACCGACCTG GTAGACAGAA GTAGAAGGGC GTAGACTAC TCGTCAACTT TAGACCTGA CGAGACAAAC

122 A G T K L E L K R T V A P S V F I F P P S D E Q L K S G T A S V T A S V V

901 TGTCGCTGCT GAAATACCTC TATCCAGAG AGGCCAAAGT ACAGTGGAAAG GTGGATAAGG CCCTCCAATC GGGTAACCTCC CAGGAGAAGTG TCAAGGAGCA  
ACACGGACGA CTATTTGAG ATAGGTCTCA TCGGTTCA TGTCACCTC CACCTATGCG GGGAGGTTAG CCCATTGAGG GTCCCTCTAC AGTGTCTGT

156 C I L N N F Y P R E A K V Q W K V D N A L Q S G N S Q E S V T E Q

1001 GAGCAGGAAG GACGGACCT ACAGGCTCG CAGCACCTG ACGGTGTAGCA AAGCAGACTA CGAGAAACAC AAAGTCTAG CCTGGCAAGT CACCCATCAG  
CTGTGTCTGC CTGTGTCTGC TGTCGAGTC GTCGACTCTG TTTCAGATGC GGACGGTTCA GTGGGTAGTC

189 D S K D S T Y S L S S T L T L S K A D Y E K H K V Y A C E V T H Q

FIG. 3-2

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1101 GGCCTGAGCT CGCCCGTCAAC AAAGAGCTTC AACAGGGAG AGTGTAAAG TGATCCTCTA CGCCGGACGC ATCGTGGCCC TAGTAGCAA GTTCACGTA  
CCGGACTCGA GGGGAGTG TTTCCTGAAG TTGCCCCCTC TOCACATTG ACTAGGAGAT GGGCTGCG TAGAACCGGG ATCTGGTT CAAGTCGATT  
222 G L S S P V T K S F N R G E C O

1201 AAAGGGTATC TAGAGGTGA GGTGATTTTA TGAAAAGAA TATGCCATT CTTCCTGGAT CTATGTTGCT TTTTCTATT GCTACAAACG CGTAGCTCA  
TTTCCCATAG ATCTCCAAC CCACTAAAT ACTTTCTCTT ATAGGTAAA GAAGAACATA GATAAACAGCA AAAAGATAA CGATGTTGC GCATGCGAGT  
1 M K K N I A F L L A S M F V F S I A T N A Y A Q

1301 GGCTTATCTG CAGGAGCTG GGCCTGAGCT GGTGCGGCCA GGAGCTAGCG TCAAGATGTC CTGTAAGCT TCTGGCTACA CCTTCACAG CTATAACATG  
CCGAATAGAC GTGTCAGAC CGGGCTCGA CCACGGCGGT OCTCGATCGC AGTCTACAG GACATTTCGA AGACCGATGT GGAGTGGTC GATATGTC  
25 A Y L Q Q S G A E L V R P G A S V K M S C K A S G Y T F T S Y N M

1401 CATTGGGTCA AGCAGACAC CAGGGAAAGGC CTGGAAATGGA TTGGAGCGAT CTATCCGGC AACGGGACAA CGAGCTATAA CCAGAAGTTC AAGGGCAAGG  
GTAACCGAT TGTCTGTGG CTCCGGTCCG GACCTAACCT AACCTGGTAA GATAGGACCG TTGGCTGTGT GCTCGTATT GCTCTCAAG TTCCGGTCC  
58 H W V K Q T P R Q L E W I G A I Y P G N G D T S E D S A V Y F C A R V V Y

1501 CCACCTGAC TGTGGACAG TCCAGGAGTA CTGGCTACAT GCAACTGAGC AGCTGAGCT CTGAGGACAG CGCTGTCAC TTTGTCCT GCGGGTCTA  
GGTAGAGCTG ACACCTGTC AGGTGTCAT GACGGATGTA CGTTGACTCG TCGGACTAA GACTCTGTC GCGACAGATG AACACAGAG CGCACCAAGT  
92 T L T V D K S S T A Y M Q L S S L T S E D S A V Y F C A R V V Y

1601 CTATAGAAC AGCTACTGGT ACTTCGACGT CTGGGTACCC GAAACCAAGC TCACCGTCTC CTCGGCCTCC ACCAAGGGCC CATCGCTCTT CCCCTGGCA  
GATATGTTG TGATGACCA TGAAGCTGCA GACCCATGG CTTGGTGTCTC AGTGGAGAG GAGCGGGAGG TGGTCCCCGG GTAGCCAGAA GGGGACCGT  
125 Y S N S Y W Y F D V W G T G T T V T V S S A S T K G P S V F P L A

1701 CCCCTCTCCA AGGACACTC TGGGGCACA GGGGCCCTGG GCTGCCTGGT CAAGGACTAC TTCCCGAAC CGGTGACGGT GTCGTGGAC TCAGGGCCC  
GGGAGGAGGT TCTGGGGAG ACCCCCCGGT CGCCGGGACC CGACGGGACCA GTTCCCTGATG AAGGGCTTG GCCACTGCCA CAGGACCTTG AGTCGCGGG  
158 P S K S T S G G T A A L G C L V K D Y F P E P V T V S W N S G A L

1801 TGACCCAGGG CGTGCACAC TTCCCGGTG TCCCTACCTC TCTAGGACTC TACTCCCTCA AGAGTGGACA AGAAAGTGA GCCCAATCT TGTGACAAA CTACACATG ACCACCGCAT  
ACTGGTGCCT GCACGTGTGG AAGGGCGAC AGGATGTCAG GAGTCCTGAG ATGAGGAGT CGTCCCTGATG AAGGGCTTG CTGGCACCA CTGGTGGTGA ACCGGTGGGT  
192 T S G V H T F P A V L Q S S G L Y S L S S V V T V P S S S L G T Q

1901 GACCTACAT TGCAACGTGA ATCACAGGCC CAGCAACACC AGGTGGACA AGAAAGTGA GCCCAATCT TGTGACAAA CTACACATG ACCACCGCAT  
CTGGATGTTAG ACGGTGCCT TAGTGTCTGG TCTCCACCTGT TCTTCACCTG CGGGTITAGA ACACGTGTTT GAGTGTGTAC TGTTGGGCTA  
225 T Y I C N V N H K P S N T K V D K K V E P K S C D K T H T O

2001 GGACCAAGTAT CGTCCATTG CACAGCATCG CCAGTCACTA TGGCGTGTG CTAGCGCGC CCTATACCTT GTCTGCCTCC CGCGGTGCG TGCGGTGCA  
CGTGGTCTATA GCAGGTAAGG CTGTCGTAGC GGTAGTGTAT ACCGCACGAC GATCGGGCG GGATGGAA CAGACGGAGG GGGCAAGC AGGCCACGT

2101 TGGAGGGGG CCACCTGAC CTGAATGGAA GCGGGGGCA CTCGCTAAC GGATTACCA CCTCCAGAAT TGGAGGCAAT GAGGTGGT GAGGTGGT GAGGTGGT  
ACCTGGCCC GTGGAGCTG GACTTACCTT CGGGCGCGT GAGGTGGT GAGGTGGT GAGGTGGT GAGGTGGT GAGGTGGT GAGGTGGT  
2201 GAATGGCAA ACCAACCTT GGCAAGACAT ATCCATGGG TCCGGCATCT CCAGGAGGG CACGGGGGC ATCTCGGGCA GCGTGGTGC CTGGCCACGG  
CTTACCGGTT TGGTGGAA CGGTAGCGC AGGGGGTAA GTGTCGTGGC GTGCGCGC TAGAGGCCGT CGCAACCCAG GACCGTGC

**FIG. 3-3**  
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2301 GTGGCGATCA TGTTGCTCT GTCTGTGAGG ACCCGGCTAG GCTGGGGGG TTGCCTACT GGTAGGAGA ATGATCACC GATA CGACGTGAA  
 CACGCCACT AGCACGAGGA CAGCAACTCC TGGCGGATC CGACGCCCCC AACGGATAGA CCAATCGTCT TACTTAGTGG CTATGGCTC GCTGGACTT  
 2401 GCGACTTGCTG CTGCAAACG TCTGCGACCT GAGCAACAA ACAGAATGGTC TTGGTTTCC GTGTTTGTAA AAGTCTGAA ACGGGAACT CAGGCCCTG  
 CGCTAACGAC GACGTTTGC AGACGTGGA CTGGTGTG TACTTACAG AACCCAAGG CACAAAGCT TTAGACCTT TGCGCCCTCA GTCGGGGAC  
 2501 CACCATATG TTCCGGATCT GCATCGCAGG ATGCTGTGG CTACCCCTGTG GAACACTAC ATCTGTATA ACAGAAGGCT GGCAATTGACC CTGAGTGT  
 GTGGTAATAC AAGGCTAGA CGTAGGTCC TAGACGACC GATGGGACAC CTGGTGTGATG TAGACATAAT TGCTTGGCA CGTAACTGG GACTCACTAA  
 2601 TTTCTCTGGT CCCGCCGAT CCATACCGCC AGTGTGTTAC CCTCACAAACG TTCCAGTAAC CGGGCATGTT CATCATCGT AACCGTATC GTGAGCATCC  
 AACGACCA GGGGGGCGTA GGTATGGGG TAACAAATG GGAGGTGTCG AACGTCAATG GCCGTACAA GTAGTAGTCA TTGGCATAG CACTCGTAGG  
 2701 TCTCTCGTT CATGGTATC ATTACCCCA TGACAGAAA TTCCCCCTTA CACGGGGCA TCAAGTGGCC AAACGGAAA AAACGGCCCT TAACATGGCC  
 AGAACGCPAA GTAGCCATAG TAATGGGGGT ACTTGTCTTT AAGGGGGAT GTGCTCCGT AGTTCATGG TTGGTCCCTT TTGGGGGA ATGGTACCGG  
 2801 CGCTTATCA GAAGCCGAC ATTACCGTT CTGGACAAAC TCAAGGAGCT GGACGGGAT GAAACGGGAG ACATCTGTA ATCGCTCAC GACCAAGCTG  
 GCGAAATAGT CTTCGGTCTG TAATTCGAA GACCTCTTGG AGTTGCTCGA CCTGGCCCTA CTGGTCCGTC TTGAGACTCT TAGCGAAGTGT CTGTCGGAC  
 2901 ATGAGCTTA CGCGAGGATC CGGAAATTGT AAACGTTAAT ATTGTGTTAA AATTGGCTT AAATTGGCTT TAATAGCT CATTTTAA CCAATGGCC  
 TACTCGAAT GGCGTGTAG GCCTTAACA TTTCGAATTA TAAACAAATT TTAGGCAA TTAAAAAAACA ATTAGTCA GTAAAAAAATT GGTATCCGG  
 3001 GAATCGGCA AAATCCCTTA TAAATCAAA GAAATGACCG AGATAGGGT GAGTGTGTT CCAGTTGGA ACAACAGTCC ACTATTAAG AACGTGGACT  
 CTTAGCCGT TTAGGGAT ATTAGTGTCTT CTATCTGGC TCTATCCCA CTCAACAA GGTAAACCT TTGTTCTCAGG TGATAAATTC TTGACACTGA  
 3101 CCPACGTCAA AGGGGAAAA ACCGTCTATC AGGGCTATGG CCCACTACTGT GAAACATCAC CCTAATCAAG TTTTTGGG TCGAGGTGCC GTAAAGCACT  
 GTTGCAGTT TCCCCTTTT TGGCAGATAG TCCCCTAAC GGTGATGCA CTGGTGTAGT GGATTAGTC AAAAACCCC AGTCACGG CATTCGTGA  
 3201 AAATCGGAC CCTAAAGGA GCCCCGATT TAGAGTTGA\_ CGGGGAAAGC CGGGCGACGT GGCAGAAAG GAGGGGAGA AAGGAAAGG ,AGGGGGGCT  
 TTAGCCCTG GGATTCCT CGGGGCTAA ATTGGAAC TGCCTTTCG GCGCTTGA CGCTCTTTC CTTCCTCTT TTGCTCTTC TCGCCCGGA  
 3301 AGGGCGCTGG CAAGTGTAGC GTTCACGCTG CGCGTTAACCA CCACACCCGC CGCGCTTAAT GCGCGCTAC AGGGCGCTGC CGCATCTGCG  
 TCCCACATCG CCAGTGGAC GCGCTTGT GTTGTGGCG GCGCGATG TCCCCTGAG GCFTAGGAGC GAGGGGAA  
 3401 TCGGTGATCA CGGTGAAAC CTCTGACACA TGCACTTCCC GGAGACGGTC ACAGCTGTG TGTAAGGGGA TGCGGGAGC AGCAAGGCC  
 AGCAACTACT GCACTTTC GAGACTGTG AGTTCAGGG CCTCTGGCAAC TGTGTACAG ACATTCGCTT ACGGGCCCT ACGGGCCCT  
 3501 GTCAAGGGGT GTGGGGGGT GTGGGGGC AGCCATGACC CAGCCCGCCA CAAACGCCCA CAGCCCGGCC CAAGTGTGAT CGTGTGCT  
 CAGTCGCCA CAGTCGCCA CAGCCCGGCC CAACGCCCA CAGTCGCCA CAGTCGCCA CAGTCGCCA CAGTCGCCA CAGTCGCCA  
 3601 TACTGAGGT GCACCATATG CGGTGTGAA TACCGCACAG ATGCGTAAGG AGAATAACC GCATCAGGG CGTGTGCTA CTGAGTGT  
 ATGACTCTCA CGTGTGATAC GCCACACTT ATGGCGTGTCTC TAGGATTTC TCTTGTAGG CGTAGTCCGC CGAATTGAT ACGGCCCTAGT CTGCTAAC  
 3701 CGGCTCGGTC GTTCGGCTGC GGCGAGGGT ATCAGCTCAC TCAAAGGGG TAATACGGT GGCTTAACTA TGCGGCATCA GAGGAGATTG  
 CGCGAGCCAG CAAGCCGAG CGCGTCCGC CGCGTCCGC AGAAGGGGA AGAAGGGAT GACTGAGGA

FIG. 3-4

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3801 GCAAAAGGCC AGCAAAGGC CAGGAACCGT AAAAAGCCG CGTGTCTGGC GTTTTCCGGC GCAAGCACCG CAAAAGGTA TCCAGGGCG CCCCTGACCA GCATCACAA ANTGACGCT CGTTTTCGG TGCTTTCGG CCAGGCGTGTG CCGACAGGAC TATAAGATA CCAGGCGTTT CCCCTGGAA GCTCCCTCGT GGCCTCTCCT GTTCCGACCC GGGACTGGT CTAGCTGGGA

3901 CAACTCAGAG GTGGCGAAC CCGACAGGAC TATAAGATA CCAGGCGTTT CCCCTGGAA GCTCCCTCGT GGCCTCTCCT GTTCCGACCC GGGACTGGT CTAGCTGGGA

4001 CGGATACCTG TCCGCCTTC TCCGCCTGGG AAGCGTGGCG CTTTCTCAT A GCTCAGCGT TAGGTATCTC AGTTCGGTGT AGGTGGTTCG CTICCAAGCTG GCCTATGGAC AGGGGAAAG AGGGGAAAG ATTCATCTAT GGTCGACCGC TCCGCAACG ATCCATAGAG TCAAGCCACA TCCAGGAAGC GAGGGTGAC

4101 GGCTGTGTC ACGAACCCC CGTTCAAGCCC GACCGGCTGG CGTTATCGG TAACATCTGT CTTGAAGTCCA ACCCGGTAAG ACACGACTA TCGCCACTGG CGAACACAGC CGAAGTGGGG CGAACAGGG ATTGATAGCC ATTGATAGCA GAACTAGGT TTGCTGTGAT ACCGGTGAAC

4201 CAGCAGCCAC TGGTACAGG ATTAGCAGG CGAGGTAATG AGGGGTGT ACAGAGTTCT TGAAGTGGT GCCTAACAC GAGGACAGT GTCTGGTG ACCATTGTC TAATGTC GCTCCATACA TCCGCCACGA TGTCTGAGA ACTCACCAC CGGATTGATG CCGATGAT CTTCTGTC

4301 ATTGGTATC TGGCCTGTC TGAAGCCAGT TACCTTCGGA AAAAGACTG GTAGCTCTG ATCAGGAA CAACACACG CTGGTAGCGG TGGTTTTT TAAACCATAG ACCTGGTCA ATGGAAGCCT TTTCCTCAC CATCGAGAAC TAGGCCGTT GTTGGTGGC GACCATCGCC ACCAAAAAA

4401 GTTGCAAGC AGCAGATTAC GCGCAGAAC TTAAGGATTC AAGAAGATCC TTGATCCTT TCTACGGGT CTGACGCTCA GTGGGACAA PACTCACGTT CAAACGTTG TCCTCTATG CGCTCTTTT TTCTCTAGG TTCTCTAGG AAACATGAA AGATGCCCA GACTGCGAAT CACCTGCTT TTGAGTGC

4501 AAGGGATT TTGGTATGAGA TTATCAAAA GGATCTTCAC CTAGATCCTT TTAAATTAA ATGAAGTT TAATCAATC TAAGTATAT ATGAGTAAC TTCCCTAAA CCAGTACTT AATAGTTTT CCTAGAAGTG GATCTAGAA AATTAAATT TTACTCAA ATTAGTTAG ATTTCATATA TACTCATTT

4601 TTGGTCTGAC AGTAACTAT GTTATATCG TGAGGCACCT ATCTAGGA TCTGCTTATT TCGTCATCC ATAGTTGCTT GACTCCCCGT CGTGTAGATA AACCAAGACTG TCAATGGTA CGAATTAGTC ACTCCGTGGA TAGAGTCGCT AGACAGATA AGCAAGTAGG TATCAACGA CTGAGGGCA GCACATCTAT

4701 ACTACGATA GGGAGGGCTT ACCATCTGGC CCCAGTGTG CAATGATACC GCGAGACCCA CGGTCACCGG CTCCAGATT ATCAGMATA AACGACCG AACCCCTCCCG GCTCGCTT GTGAGGACCG CTTCTGGGT GCGAGTGGCC GAGGTCTAAA TAGTCGTTAT TGGTCTGGTC

4801 CCGGAAGGGC CGAGCGAGA ACTGCTCCTG CAACTTATC CGCTCTCCAT CAGTCATTAA ATTGTTGCCG GGAAGCTAGA GTAAAGTAGT CGCCAGTTAA ATCAAAACCGG TTGCTGCTT TCACAGGAC GTTGAATATAG GCGAGGTAG GTCAAGATAAT TAACAAACGG CCTTCGATCT CATTCTCAA GGCGTCAATT

4901 TAGTTGCGC AACCTGTG CCAATGCTGC AGGCATCTG TGTCAGCTT CCGTGGTGG TAGTCCTCA TTCAAGCTCG ATGAGGGCA ATCAAAACCGG TTGCTGCTT GTGAGGACG TCGTAGCAC CACAGTCGA GCAGCAAC ATACCGAAGT AAGTCAGGGC CAGGGTTCG TAGTTGGCT

5001 GTACATGAT CCCCTATTT GTGCAAAAAA GCGGTAGCT CCTTCGTTCC TCCGATCGT GTTCAAGACTA AGTTGGCCG AGTGTATCA CTCAATGGTTA CAATGACTA GGGGTACAA CACGTTTTT CGCCAAATCGA GGIAAGCCAG AGGCTAGCA CAGTCCTCAT TCAAAATAGT GAGTACCAT

5101 TGGCAGGACT GCATAATTCT CTTACTGTCA TGCATCGTGTG CAGATGCTT TCTGAGTACTG GTGAGTACTG AAGCAAGTC TCTCTGAGAAT ACTCTATGGC ACCTGCTGTA CGTATTAGA GAATGACAGT AGGTAGGCA TCCAACTGAA CACTCATGAG TTGGTTCACT AAGACTCTTA TCACATAGC CGTGGCTCA ACCGAAACG CGGGCTCAAC ACCGGGATAAT ATAGCAGAAC TTCTAGAA AGACACTGAC CACTCATGAG TTGGTTCACT AAGACTCTTA TCACATAGC

5201 GCACCCGACT TGGCTCTGCC CGGGCTCAAC ACCGGGATAAT ATAGCAGAAC TTCTAGAA AGACACTGAC CACTCATGAG TTGGTTCACT AAGACTCTTA TCACATAGC CGTGGCTCA ACCGAAACG CGGGGGTTG TGCCCTATTAA TGGTAGTAAAC CTTTGCAG GAGCCCCGCT

**FIG. 3-5  
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5301 AAGACTCTCAA GGATCTTACCG CCGTTGAGA TCCAGTTGCA TGTAACCCAC TC GTGTGACCC AACTGATCTT CAGCATCTT TACTTTCACC AGCGTTTCTG  
 TTGAGAGTT CCTAGAAATGG CGACAACCTCT AGGTCAAGCT ACATTTGGTG AGCAGTGGG TTGACTAGAA GTCGTAGAAA ATGAAAGTGG TCGCAAAGAC  
  
 5401 GGTCAGCAA AACAGGAAGG CAAATGCCG C2AAAAGGG ATAAGGGCG ACACGGAAAT GTGAAATACT CATACTCTC CTTTTCATT ATTATTGAAG  
 CCACTCGTT TTGTCCTCC GTTTACGCC GTTTTCCC TTATCCGC TTGTGCTTAA CAACCTATGA GTATGAGAG GAAAAGTTA TAATAACTTC  
  
 5501 CATTATCAG GTTATTGTC TCATGAGCGG ATACATATT GAATGTTTT AGAAAATAAA ACAAAATAGGG GTTCCGGCGCA CATTCCCCG AAAAGTGCCA  
 GTAAATAGTC CCAATAACAG AGTACTCGCC TAGTGTATAAA CTTACATAAA TCTTTTATT TGTTTATCCC CAAGGGCGT GTAAAGGGC TTTTCACGGT  
  
 5601 CCTGACGTCT AAGAAACCAT TATTATCTG ACATTAACCT ATAAAAATAG GCGTATCAG AGGCCCTTC GTCTTCAA  
 GCACTGCGA TTCPTTGGTA ATAATAGTAC TGTAAATGGG TATTTTAAC CGCATAGTGC TCCGGGAAG CAGAAGTT

FIG. 4 - plasmid pDR1

TTGAGCTGCCGACATTGATTATTGACTAGTTATTAATAGTAATCAATTACGGGGTCA  
 TTAGTCATAGCCCATATATGGAGTTCGGCTTACATAACTACGTAAATGGCCCGCCT  
 GGCTGACCGCCAACGACCCCCGGCCATTGACGTAAATATGACGTATGTTCCCATAGTA  
 ACGCCAATAGGGACTTCCATTGACGTAAATGGGTGGAGTATTTACGGTAAACTGCCAC  
 TTGGCAGTACATCAAGTGTATCATATGCCAAGTACGCCCTATTGACGTAAATGACGGT  
 AAATGGCCCGCTGGCATTATGCCAGTACATGACCTTATGGGACTTCTACTTGGCAG  
 TACATCACCGTATTAGTCATCGCTATTACCATGGTGTGGGGTTGGCAGTACATCAAT  
 GGGCGTGGATAGCGGTTGACTCACGGGATTCCAAAGTCTCCACCCCATTGACGTAAAT  
 GGGAGTTGTTGGCACCAAAATCAACGGGACTTCCAAAATGTCGTAACAACACTCCGCC  
 CCATTGACGCAAATGGGCGGTAGGGGTGTACGGTGGGAGGTCTATAAAGCAGAGCTCGT  
 TTAGTGAACCGTCAGATGCCCTGGAGACGCCATCCACGCTTTGACCTCCATAGAAGA  
 CACCGGGACCGATCCAGCCTCCGGCCGGGACGGTGATTGGAACGGGATTCCCCGT  
 GCCAAGAGTACGTAAGTACCGCTATAGACTATAGGCCAACCCCTGGCTCGTTA  
 GAACGGGCTACAATTAATACATAACCTTATGTATCATACACATAACGATTAGGTGACAC  
 TATAGAATAACATCCACTTGCCCTTCTCTCCACAGGTGTCCACTCCAGGTCCAACACTGC  
 ACCTCGGTTCTATCGATTGAATTCCACATGGGATGGTCATGTATCATCCTTTCTAGT  
 AGCAACTGCAACTGGAGTACATTAGATATCCAGATGACCCAGTCCCCGAGCTCCCTGTC  
 CGCCTCTGGGGCATAAGGTCAACCATCACCTGCCAGTCAGGACATCCGTAATT  
 TTTGAACCTGGTATCAACAGAAACCAGGAAAGCTCGAAACTACTGATTACTATACCTC  
 CGCCTGGAGTCTGGAGTCCCTCTCGCTCTGGTTCTGGGACGGATTACAC  
 TCTGACCATCAGTAGTCTGCAACCCGGAGGACTCGCAACTTATTACTGTCAGCAAGGTAA  
 TACTCTGCCGTGGACGGTCCGGACAGGGCACCAAGGTGGAGATCAAACGAACTGTGGCTGC  
 ACCATCTGCTTCATCTCCGCCATCTGATGAGCAGTGAAATCTGAAACTGCTCTGT  
 TGTGTGCTGCTGAATAACTCTATCCAGAGAGGCCAAAGTACAGTGGAAAGGTGGATAA  
 CGCCCTCCAATGGGTAACCTCCAGGAGAGTGTACAGAGCAGGACAGCAAGGACAGCAC  
 CTACAGCCTCAGCAGCACCCCTGACGTGAGCAAAGCAGACTACGAGAAACACAAAGTCTA  
 CGCCTGCGAAGTCACCCATCAGGGCTGAGCTGCCGTACAAAGAGCTTCAACAGGGG  
 AGAGTGTTAAGCTGGGCCATGGCCAACCTGTTATTGAGCTTATAATGGTTACAA  
 ATAAAGCAATAGCATCACAAATTCAACAAATAAGCATTTTTCACTGCATTAGTTG  
 TGTTTGTCCAAACTCATCAATGTATCTTATCATGTCGGATCGATGGAAATTAAATTG  
 GCGCAGCACCATGGCTGAAATAACCTCTGAAAGAGGAACCTGGTTAGGTACCTCTGAG  
 GCGGAAAGAACAGCTGTGGAATGTGTGTCAGTTAGGGTGTGAAAGTCCCAGGCTCC  
 CAGCAGGAGAAGTATGCAAAGCATGCATCTCAATTAGTCAGCAACCAGGTGTGGAAAGT  
 CCCCAGGCTCCCAGCAGGAGTATGCAAAGCATGCATCTCAATTAGTCAGCAACCA  
 TAGTCCCGCCCTAACTCCGCCATCCGCCCTAACTCCGCCAGTCCGCCATTCTC  
 CGCCCATGGCTGACTAATTTTTATTGAGCAGAGGCCGAGGCCGCTGGCCTCTG  
 AGCTATTCCAGAAGTAGTGGAGGCTTTGGAGGCTAGGTTTGCAAAAGCTGT  
 TAACAGCTGGCACTGCCGTGTTTACAACGTCGTGACTGGAAAACCTGGCTTAC  
 CCAACTTAATCGCCTTGCAAGCACATCCCCCTCGCCAGCTGGCTAAAGCGAAGAGGC  
 CGCACCAGATGCCCTCCCAACAGTTGCGTAGCCGTAAAGCGAATGGCGCTGATGCG  
 GTATTTCTCTTACGCATCTGCGGTATTCAACACCGCATACGTCAAAGCAACCATAG  
 TACGCCCTGTAGCGCGCATTAGCGCGGGGTGTTACGCGCAGCGTGACC  
 GCTACACTTGCCAGCGCCCTAGCGCCGCTCCCTTCGCTTTCTCCCTTCTCGCC  
 ACGTTGCGGGCTTCCCGTCAAGCTCTAAATGGGGCTCCCTTGGGTTCCGATT  
 AGTGTCTTACGGCACCTCGACCCAAAAACTGATTGGGTGATGGTTACGTAGTGG  
 CCATCGCCCTGATAGACGGTTTGCCTTGCAGTTGGAGTCAACGTTCTTAATAGT  
 GGACTCTTGTCCAAACTGGAACAAACTCAACCCCTATCTGGCTATTCTTTGATT  
 TAAGGGATTGGCGATTGCGCTATTGGTAAAGGAAACTCCGCTACGTGACTGGGT  
 TGCTCTGATGCCGATAGTTAACGTTACAATTGAGCTGATTAAACAAAATT  
 AACCGGAATTAAACAAATTTAACGTTACAATTGAGCTGACTCTCAGTACAATC  
 TGCTCTGATGCCGATAGTTAACGTTACAATTGAGCTGACTGGGT  
 CGCCCGACACCCGCCAACACCCGCTGACGGGCTTGTCTGCCGGCAT

FIG. 4 - cont'd

CCGCTTACAGACAAGCTGTGACCGTCTCCGGAGCTGCATGTGTCAGAGGTTTCACCGT  
 CATCACCGAAACCGCGAGGCAGTATTCTGAAGACGAAAGGGCTCGTATAACGCCTAT  
 TTTTATAGGTTAATGTCATGATAATAATGGTTCTTAGACGTCAGGTGGCACTTTCGGG  
 GAAATGTGCGCGAACCCCTATTGTTATTTCTAAATACATTCAAATATGTATCCGC  
 TCATGAGACAATAACCTGATAAAATGCTFCATAATAATTGAAAAAGGAAGAGTATGAGTA  
 TTCAACATTCCGTGTCGCCCTTATTCCCTTTTGCGGCATTTGCCCTCGTGTGTTG  
 CTCACCCAGAAACGCTGGTGAAGTAAAAGATGCTGAAGATCAGTTGGTGCACGAGTGG  
 GTTACATCGAACTGGATCTCAACAGCGTAAGATCCTGAGAGTTTCGCCCGAAGAAC  
 GTTTCCAATGATGAGCACTTTAAAGTCTGCTATGTGGCGGTATTATCCCCTGATG  
 ACGCCGGCAAGAGCAACTCGGTGCCGCATACACTATTCTCAGAATGACTTGGTTGAGT  
 ACTCACCAGTCACAGAAAAGCATTTACGGATGGCATGACAGTAAGAGAATTATGCAGTG  
 CTGCCATAACCATGAGTGATAACACTGCGGCCAACTTACTTCTGACAACGATCGGAGGAC  
 CGAAGGAGCTAACCGCTTTTGACAACATGGGGATCATGTAACTCGCCTGATCGTT  
 GGGAACCGGGAGCTGAATGAAGCCATACCAAACGACGAGCGTACACACCACGATGCCAGCAG  
 CAATGGCAACAAACGTTGCGAAACTATTAACTGGCGAACTACTTACTCTAGCTTCCC  
 AACAAATTAAAGACTGGATGGAGGCGATAAAAGTTGAGGACCACTTCTGCGCTCGGCC  
 TTCCGGCTGGCTGGTTATTGCTGATAAAATCTGGAGCCGGTGGCTGGTCTCGCGTA  
 TCATTGCGACTGGGCCAGATGGTAAGCCTCCCGTATCGTAGTTATCTACACGACGG  
 GGAGTCAGGCAACTATGGATGAACGAAATAGACAGATCGCTGAGATAGGTGCCACTGA  
 TTAAGCATTGGTAACTGTCAGACCAAGTTACTCATATAACTTTAGATTGATTAAAAC  
 TTCATTTTAATTAAAGGATCTAGGTGAAGATCCTTTGATAATCTCATGACCAAA  
 TCCCTTAACGTGAGTTTCGTTCACTGAGCGTCAGACCCCGTAGAAAAGATCAAAGGAT  
 CTTCTTGAGATCCTTTCTGCGCGTAACTGCTGCTGCAAACAAAAAACACCACGC  
 TACCAAGCGGTGGTTGCGGATCAAGAGCTACCAACTTTCCGAAGGTAACTG  
 GCTTCAGCAGAGCGCAGATAACCAAAACTGTCCTCTAGTGTAGGCCCTAGG  
 ACTTCAAGAACTCTGAGCACCCTACATACTCGCTCTGTAATCCTGTTACCAACTGG  
 CTGCTGCCAGTGGCGATAAGTCGTCTTACGGGGTTGGACTCAAGACGATAGTTACCG  
 ATAAGGCGCAGCGGTGGGCTGAAACGGGGTTGCGCACACAGCCCAGCTGGAGCGAA  
 CGACCTACACCGAAGTACGAGATACTACAGCGTGGAGCATTGAGAAAGCGCCACG  
 AAGGGAGAAAGCGGACAGGTATCCGTAAGCGGCAGGGTGGAACAGGGAGAGCGCACGA  
 GGGAGCTTCAGGGGAAACGCCCTGGTATCTTATAGTCTGTCGGGTTTCGCCACCTCT  
 GACTTGAGCGTCGATTGGTATGCTCGTCAGGGGGCGGAGCTATGAAACGCC  
 GCAACCGCCCTTTACGGTTCTGGCTTTGCTGGCTTTGCTCACATGTTCTTC  
 CTGCGTTATCCCTGATTCTGAGATAACCGTATTACCGCTTGAGTGAGCTGATACCG  
 CTCGCCGCAGCGAACGACCGAGCGCAGCGAGTCAGTGAGCGAGGAAGCGGAAGAGCGCC  
 CAATACGCAAACCGCTCTCCCCGCGCTGGCGATTCAATTAACTCAGCTGGCACGACA  
 GGTTCCCGACTGGAAAGCGGGCAGTGAGCGCAACGCAATTATGTGAGTTACCTCACTC  
 ATTAGGCACCCAGGCTTACACTTATGCTTCCGGCTCGTATGTTGTGGAATTGTGA  
 GCGGATAACAATTACACAGGAAACAGCTATGACCATGATTACGAATTAA

FIG. 5 - plasmid pDR2

ATTGAGCTCGCCGACATTGATTATGACTAGTTATAATAGTAATCAATTACGGGGTC  
 ATTAGTTCATAGCCATATATGGAGTTCCCGTACATAACTTACGGTAAATGGCCCGCC  
 TGGCTGACGCCAACGACCCCCCCCATTGACGTCAATAATGACGTATGTTCCCATACT  
 AACGCCAATAGGGACTTCCATTGACGTCAATGGGTGAGTATTACGGTAAACTGCCA  
 CTTGGCAGTACATCAAGTGTATCATATGCCAAGTACGCCCTATTGACGTCAATGACGG  
 TAAATGGCCGCCTGGCATTATGCCAGTACATGACCTTATGGGACTTTCTACTTGGCA  
 GTACATCTACGTATTAGTCATCGTATTACCATGGTGATGCGGTTTGGCAGTACATCAA  
 TGGCGTGGATAGCGGTTTGACTCACGGGATTTCACGGTCTCCACCCATTGACGTCAA  
 TGGGAGTTGTTGGCACCAAAATCAACGGGACTTCCAAAATGTCGTAACAACCTCCGC  
 CCCATTGACGCCAATGGCGGTAGGCGTGTACGGTGGGAGGTCTATATAAGCAGAGCTCG  
 TTAGTGAACCGTCACTGCCCTGGAGACGCCATCCACCGTGTGTTGACCTCCATAGAAG  
 ACACCGGGACCGATCCAGCCTCCGGGGGGAACGGTGCATTGAAACCGGGATTCCCCG  
 TGCCAAGAGTGAAGTACCTGAGTACATTGAGTCTATAGGCCCACCCCTTGGCTTCGTT  
 AGAACGGCTACAATTAAATACATAACCTTATGTTACATACACATACGATTAGGTGACA  
 CTATAGAATAACATCCACTTTGCTTCTCTCCACAGGTGTCACCTCCAGGTCCAACCTG  
 CACCTCGTTCTATGATTGAAATCCACCATGGGATGGTCATGTATCATCCTTTCTAG  
 TAGCAACTGCAACTGGAGTACATTGAGTCAAGGTTAGCTGGTGGAGTCTGGCGGTGGCCTGG  
 TGCAGCCAGGGGCTCACTCCGTTGTCCTGTGAGCTCTGGCTACTCCTTACCGGCT  
 ACACATGAACTGGGTGCGTCAGGCCAGGTAAGGGCTGGAATGGGTTGCACTGATTAA  
 ATCCTTATAAAGGTGTTACTACCTATGCCGATAGCGTCAAGGGCGTTCACTATAAGCG  
 TAGATAAAATCCAAAACACAGCCTACCTGCAAATGAAACAGCCTGCGTGAGGACACTG  
 CCGTCTATTATTGTCAGAACGGGATACTACGGGATAGCGACTGGTATTGACGTCT  
 GGGGTCAAGGAACCTGGTCACCGTCTCCTCGGCTCACCAGGGCCATCGGTCTTCC  
 CCCTGGCACCTCCTCCAAGAGCACCTCTGGGGCACAGCGGCCCTGGGCTGCCTGGTCA  
 AGGACTACTCCCCAACCGGTGACGGTGTGAGTCACTCAGGCGCCCTGACCAGCGGCG  
 TGCACACCTCCGGCTGTCCTACAGTCCTCAGGACTCTACTCCCTCAGCAGCGTGGTGA  
 CTGTGCCCTCTAGCAGCTGGCACCCAGACCTACATCTGCAACGTGAATACAAGCCCA  
 GCAACACCAAGGTGGACAAGAAAGTTGAGCCAAATCTTGTGACAAAACACACATGCC  
 CACCGTCCCCAGCACCTGAACCTCTGGGGGACCGTCAGTCTCCTCTCCCCAAAAC  
 CCAAGGACACCCCTCATGATCTCCGGACCCCTGAGGTACATGCGTGGTGGACGTGA  
 GCCACGAAGACCTGGAGGTCAAGTCAACTGGTACGTGACGGCGTGGAGGTGCATAATG  
 CCAAGACAAAGCCGGAGGAGCAGTACAACACAGCACGTACCGTGTGGTCAGCGTCTCA  
 CGTCCTGCACCAGGACTGGCTGAATGGCAAGGAGTACAAGTGCAGGTCTCCAACAAAG  
 CCCTCCCAGCCCCATCGAGAAAACATCTCAAAGCCAAAGGGCAGCCCCGAGAACAC  
 AGGTGTACACCCCTGCCCATCCGGAAAGAGATGACCAAGAACAGGTCAAGCCTGACCT  
 GCCTGGTCAAAGGCTCTATCCCAGCGACATCGCGTGGAGTGGAGAGCAATGGGCA  
 CGGAGAACAACTACAAGACCACGCCCTCCCGTGTGGACTCCGACGGCTCTTCTCCT  
 ACAGCAAGCTACCGTGGACAAGAGCAGGTGGCAGGGGAACGTCTCTCATGCTCCG  
 TGATGCATGAGGCTCTGCACAACCAACTACACGCGAGAGGCTCTCCCTGTCTCCGGTA  
AATGAGTGCACGGCCTAGAGTCGACCTGCAAGCTGGCCCATGGCCAACCTGT  
 TTATTGCACTTATAATGGTTACAAATAAGCAATAGCATCACAAATTTCACAAATAAG  
 CATTTTTCACTGCATTCTAGTGTGGTTGTCAAACACTCATCAATGTATCTTATCATG  
 TCTGGATCGATCGGAATTAAATCGGCGCAGCACCATGGCCTGAAATAACCTCTGAAAGA  
 GGAACCTGGTAGGTACCTCTGAGGCGGAAAGAACCATCTGTGGAATGTGTGTCAGTTA  
 GGGTGTGGAAAGTCCCCAGGCTCCCCAGCAGGGCAGAAGTATGCAAAGCATGCATCTCAAT  
 TAGTCAGCAACCAGGTGGAAAGTCCCCAGGCTCCCCAGCAGGGCAGAAGTATGCAAAGC  
 ATGCATCTCAATTAGTCAGCAACCATAGTCCCCCTAACTCCGCCCCATCCGCCCCCTA  
 ACTCCGCCAGTCCGCCATTCTCCGCCATTGGCTGACTAATTTTTATTTATGCA  
 GAGGCCGAGGCCCTCGGCCCTGAGCTATTCCAGAAGTAGTGTGAGGAGGCTTTTGA  
 GGCCTAGGCTTTGCAAAAGCTGTTAACAGCTGGACTGCCGTGTTACAACGTC  
 GTGACTGGAAAACCCCTGGCGTTACCCAACTTAATCGCCTGAGCACATCCCCCTTCG

FIG. 5 Cont.'d

CCAGTTGGCGTAATAGCGAAGAGGCCGACCGATGCCCTTCCAAACAGTTGCGTAGCC  
 TGAATGGCGAATGGCGCTGATGCGGTATTTCCTCTACGCATCTGCGGTATTCAC  
 ACCGCATACTCAAGAACCATAGTACGCCCTGTAGCGCGCATTAAGCGCGCGGG  
 TGTTGGTGGTTACCGCGACCGCTACACTTGCCAGCGCCCTAGCGCCGCTCCTT  
 CGCTTCTCCCTTCTGCCACGTTGCCGGCTTCCCCGTCAAGCTCTAAATCG  
 GGGGCTCCCTTAGGGTCCGATTAGTCTTACGGCACCTCGAACCCAAAAACTTGA  
 TTGGGTGATGGTCACTAGTGGCCATGCCCTGATAGACGGTTTCGCCCTTGAC  
 GTTGGAGTCACGTTCTTAATAGTGGACTTGTGTTCAAACAGGAACAACACTCAACCC  
 TATCTGGGCTATTCTTGATTATAAGGGATTTCGCCGATTGCCCTATTGGTAA  
 AAATGAGCTGATTTAACAAAATTAAACGAAATTAAACAAAATTAAACGTTACAAT  
 TTATGGTCACCTCACTGATGCCCATAGTTAACGAAACTCCGCTA  
 TCGCTACGTAACGGTGCATGGCTGCCGGACACCCGCAACACCGCTGACCGCCC  
 TGACGGCTGTCTGCCGGCATCCGCTACAGACAAGCTGTGACCGCTCCGGAGC  
 TGATGTGTCAGAGGTTTACCGTCATCACCAGAACCGCGAGGCAGTATTCTGAAGA  
 CGAAAGGGCTCGTGTACGCCATTAGGTTAGTGTATGATAATAATGGTTCT  
 TAGACGTCAGGTGGCAGTTGGAAATGTCGCGGAACCCCTATTGTTATTTC  
 TAAATACATTCAAATATGTATCCGCTCATGAGACAATAACCCGTATAATGCTCAATAA  
 TATTGAAAAGGAAGAGTATGAGTATTCAACATTCCGTGTCGCCCTATTCCCTTTT  
 GCGGCATTGCTCCTGTTGCTCACCAAGAACCGCTGGTAAAGTAAAAGATGCT  
 GAAGATCAGTGGGTGACGAGTGGTTACATGAACTGGATCTCAACAGCGGTAAGATC  
 CTTGAGAGTTTCGCCCGAAGAACGTTCCAATGATGAGCACTTTAAAGTTCTGCTA  
 TGCGCGGTATTATCCGTGATGACGCCGGCAAGAGCAACTCGGTGCCCATACAC  
 TATTCTCAGAATGACTGGTGAGTACTCACCAAGTCACAGAAAAGCATCTACGGATGGC  
 ATGACAGTAAGAGAATTATGCAGTGCTGCCATAACCATGAGTGATAACACTGCGGCCAAC  
 TTACTCTGACAACGATCGGAGGACCGAAGGAGCTAACCGCTTTTGCAACACATGGGG  
 GATCATGTAACTCGCCTGATCGTGGAACCGGAGCTGAATGAAGCCATACCAACGAC  
 GAGCGTGCACACCACGATGCCAGCAGCAATGCCAACACGTTGCCAAACTATTAACTGGC  
 GAACTACTTACTCTAGCTCCCGCAACAATTAAAGACTGGATGGAGGCGGATAAAAGTT  
 GCAGGACCACTCTGCCCTCGGCTGGCTGGTTATTGCTGATAAAATCTGGA  
 GCCGGTGAGCGTGGGCTCGCGGTATCATTGCACTGGGCCAGATGGTAAGCCCTCC  
 CGTACGTTATCTACAGACGGGAGTCAGGCAACTATGGATGAACGAAATAGACAG  
 ATCGCTGAGATAGGTGCTCACTGATTAAGCATTGTAACTGTCAGACCAAGTTACTCA  
 TATATACTTAGATTGATTAAAACCTCATTTAAATTAAAGGATCTAGGTGAAGATC  
 CTGTTGATAATCTCATGACCAAAATCCCTAACGTGAGTTCTGTTCACTGAGCGTCA  
 GACCCCGTAGAAAAGATCAAAGGATCTCTGAGATCCTTTCTGCCGTAATCTGC  
 TGCTGCAAACAAAAACACCACCGCTACCAGCGTGGTTGCTGCCGATCAAGAGCTA  
 CCAACTCTTTCCGAAGGTAACTGGCTTCAGCAGAGCGCAGATAACAAATACTGCTCT  
 CTAGTGTAGCGTAGTTAGGCCACCACTCAAGAACTCTGAGCACCGCTACACAC  
 GCTCTGCTAATCTGTTACAGTGGCTGCTGCCAGTGGCATAAGTCGTGCTTACGGG  
 TTGGACTCAAGACGATAGTTACCGATAAGCGCAGCGTGGCTGAACGGGGGTTCG  
 TGACACAGCCCAGCTGGAGCGAACGACCTACACCGAACTGAGGATACCTACAGCGTGA  
 CATTGAGAAAGCGCCACGCTCCGAAGGGAGAAAGCGGACAGGTATCGGTAAGCGGC  
 AGGGTCGGAACAGGAGAGCGCAGGAGGGAGCTCCAGGGGAAACGCCCTGGTATCTTAT  
 AGTCCTGTCGGGTTGCCACCTCTGACTTGAGCGTCACTTGTGATGCTCGTCAGGG  
 GGGCGGAGCCTATGGAAAACGCCAGCAACGCCCTTTACGTTCTGCCCTTGC  
 TGGCCTTTGCTCACATGTTCTGCCGTTATCCCTGATTCTGTTGATAACCGTATT  
 ACCGCCCTTGAGTGTGAGCTGATACCGCTGCCAGCCGAACGACCGAGCGCAGCGAGTC  
 GTGAGCGAGGAAGCGGAAGAGCGCCAAATACGCAAACCGCTCTCCCGCGCGTTGGCCG  
 ATTCAATTAACTCAACTGGCACGACAGGTTCCGACTGGAAAGCGGGAGTGAAGCGAAC  
 GCAATTAAATGTGAGTACCTCACTCATTAGGCACCCAGGCTTACACTTTATGCTTCCG  
 GCTCGTATGTTGTGGAATTGTGAGCGGATAACAATTACACAGGAAACAGCTATGAC  
 CATGATTACGAATTA

**FIG. 6**

hu2H7.v16 L chain [232 aa]

MGWSCIILFLVATATGVHSDIQMTQSPSSLASVGDRVTITCRASSSVSYMHWYQQKPGK  
APKPLIYAPSNLASGVPSRFSGSGSGTDFTLTISSLQPEDFATYYCQQWSFNPPTFGGQT  
KVEIKRTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQES  
VTEQDSKDSTYSLSSTLTLKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC

## FIG. 7

hu2H7.v16 H chain [471 aa]

MGWSCIILFLVATATGVHSEVQLVESGGGLVQPGGSLRLSCAASGYTFTSYNMHWVRQAP  
GKGLEWVGAIYPGNGDTSYNQKFKGRFTISVDKSNTLYLQMNSLRAEDTAVYYCARVY  
YSNSYWYFDWGQGTLVTVSSASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTV  
SWNSGALTSGVHTFPALVQSSGLYSLSSVTVPSLGTQTYICNVNHKPSNTKVDKKVE  
PKSCDKTHTCPPCAPEELLGGPSVFLFPPPCKDTLMISRTPETCVVVDVSHEDPEVKFN  
WYVDGVEVHNAAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTI  
SKAKGQPREGQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTPP  
VLDSDGSFFLYSKLTVDKSRWQQGNVFCSVHEALHNHYTQKSLSLSPGK

**FIG. 8****hu2H7.v31\_H chain [471 aa]**

MGWSCIILFLVATATGVHSEVQLVESGGGLVQPGGSLRLSCAASGYTFTSYNMHWVRQAP  
GKGLEWVGAIYPNGDTSYNQKFKGRFTISVDKSNTLYLQMNSLRAEDTAVYYCARVY  
YSNSYWYFDVWGQGTLVTVSSASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTV  
SWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKKVE  
PKSCDKTHTCPGPCPAPELLGGPSVFLFPKPKDILMISRTPETCVVVDVSHEDEVKFN  
WYVDGVEVHNAAKTKPREEQYNATYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIAATI  
SKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPP  
VLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK

FIG. 9

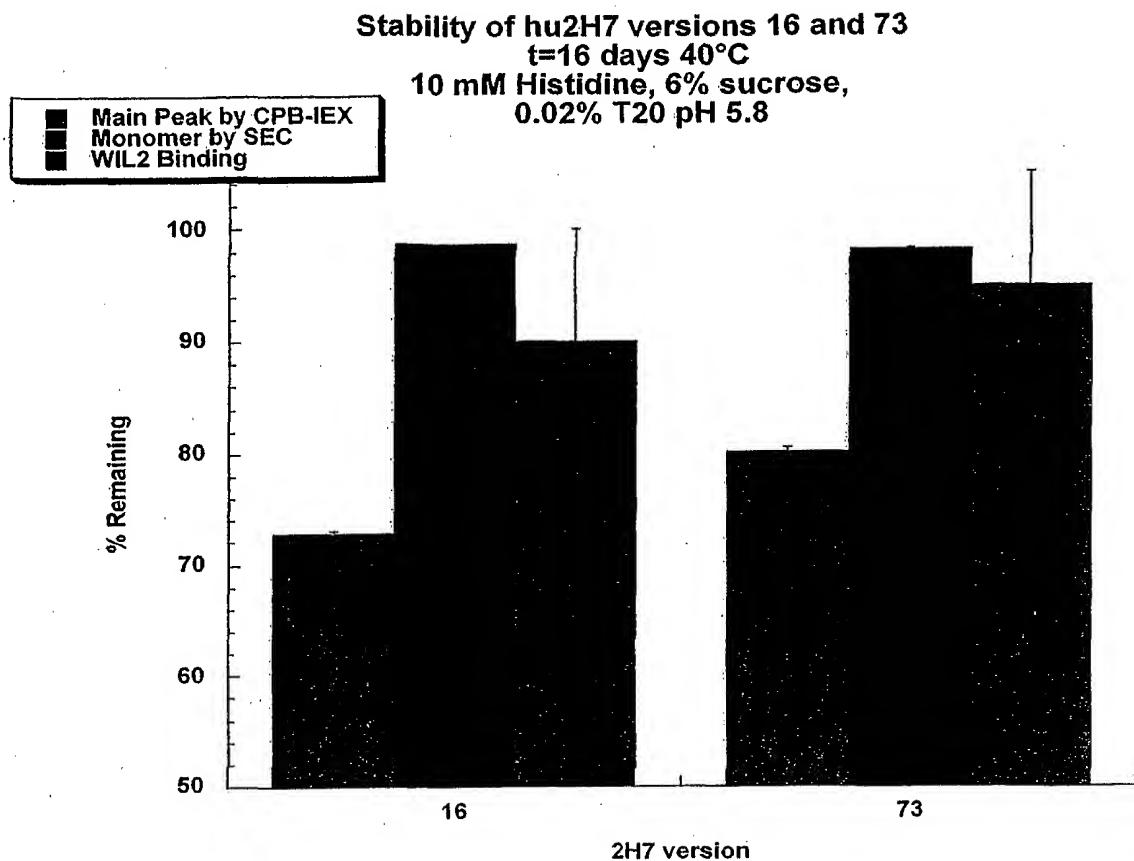


FIG. 10

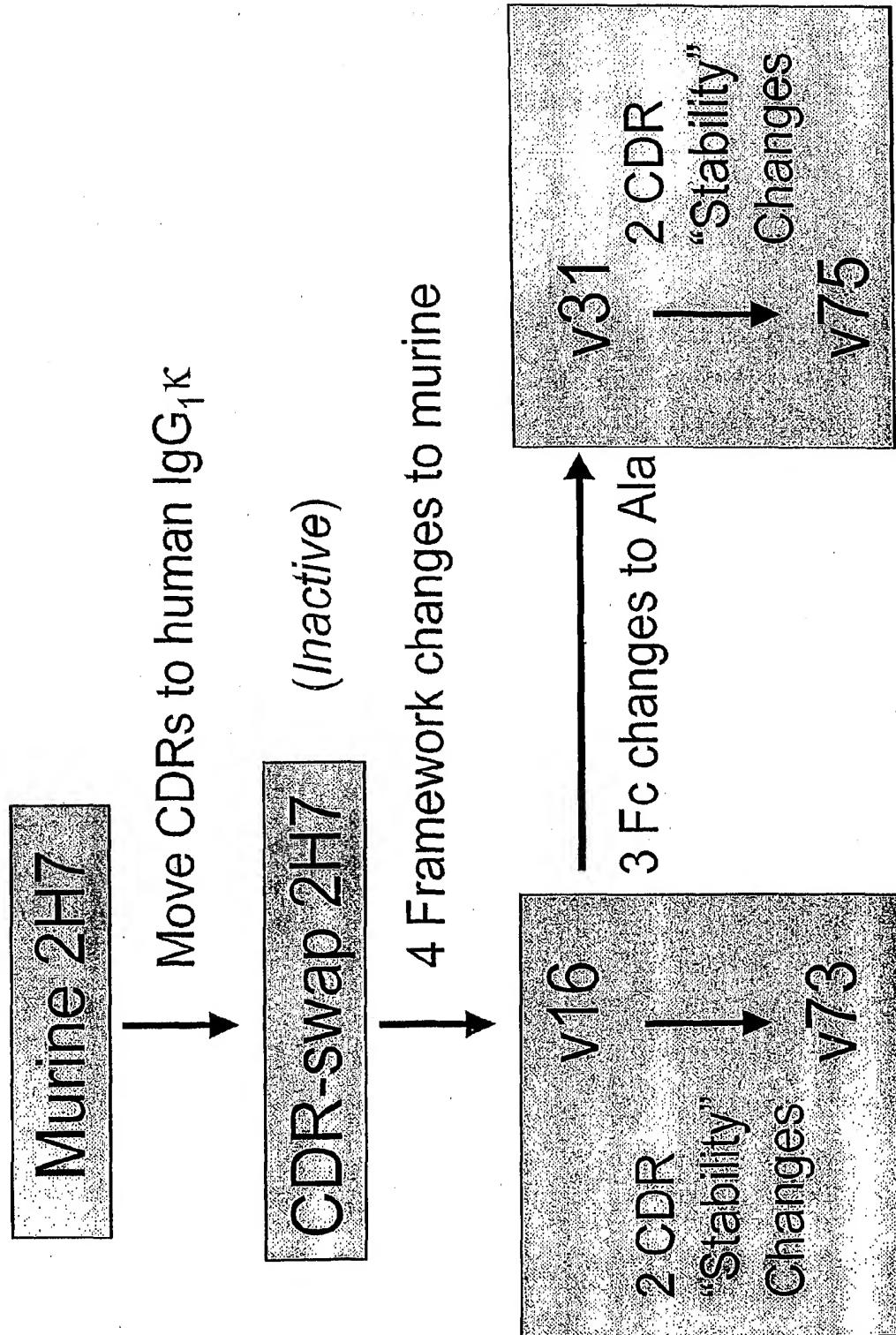


FIG. 11

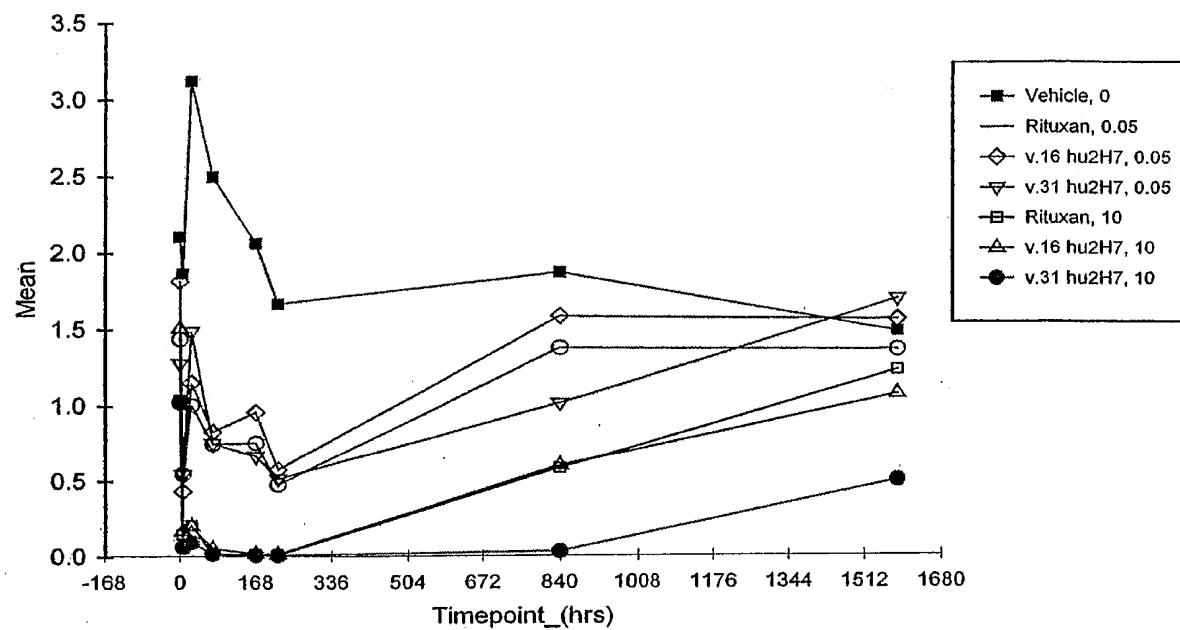
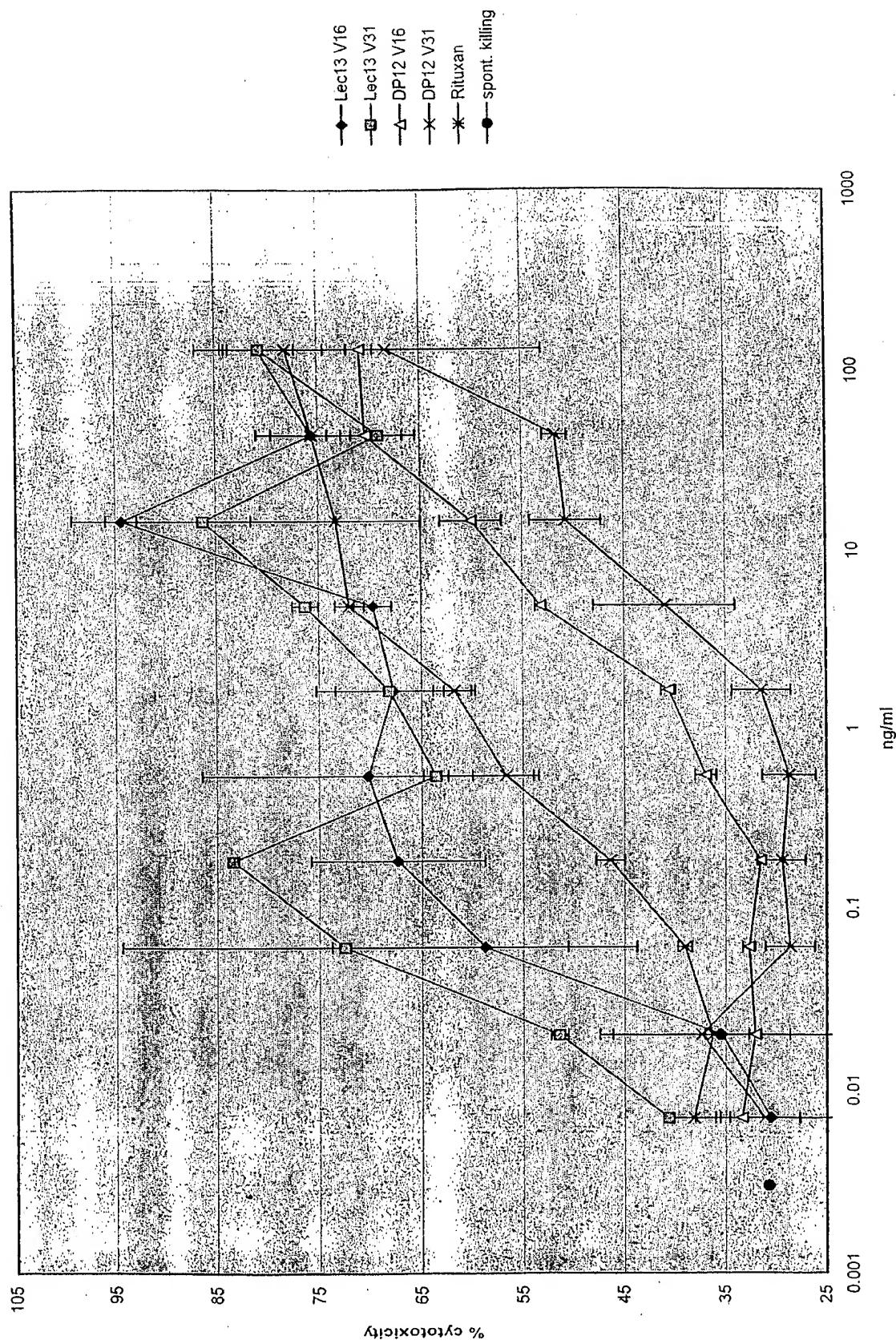
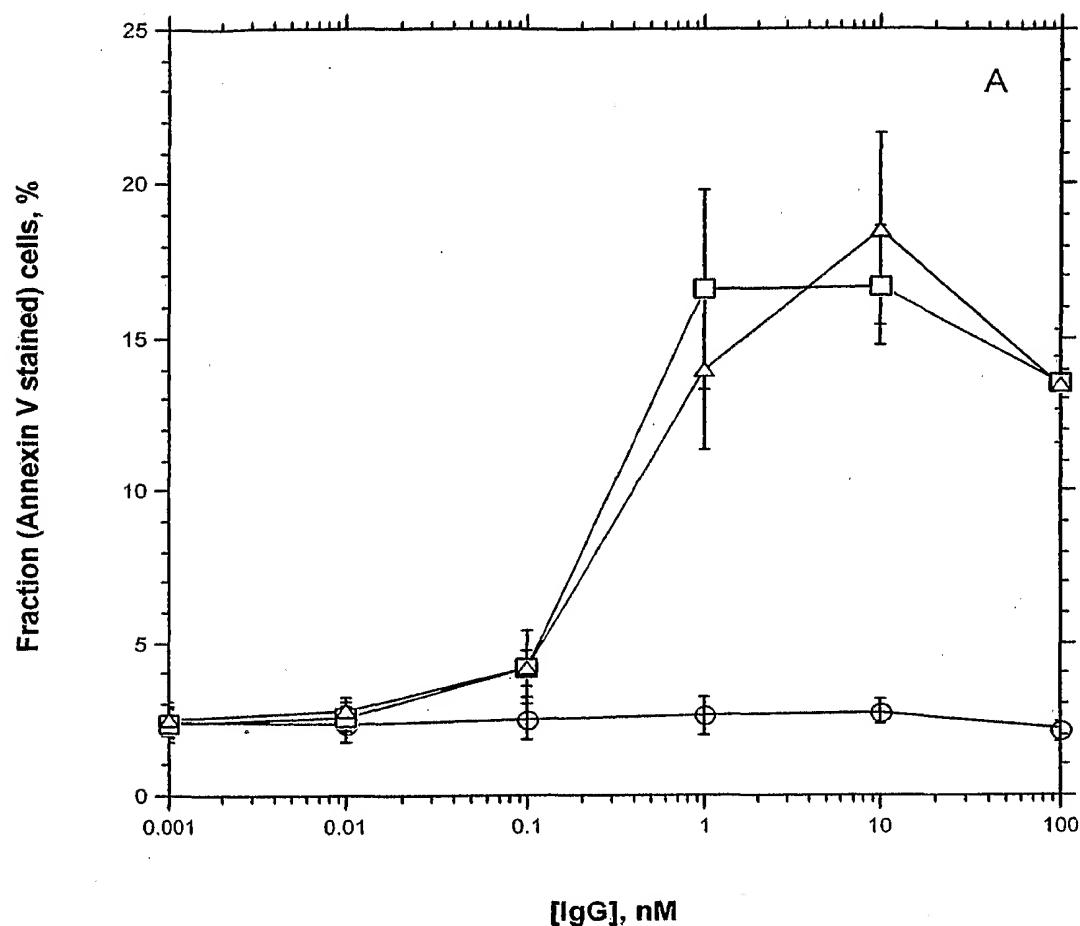


FIG. 12

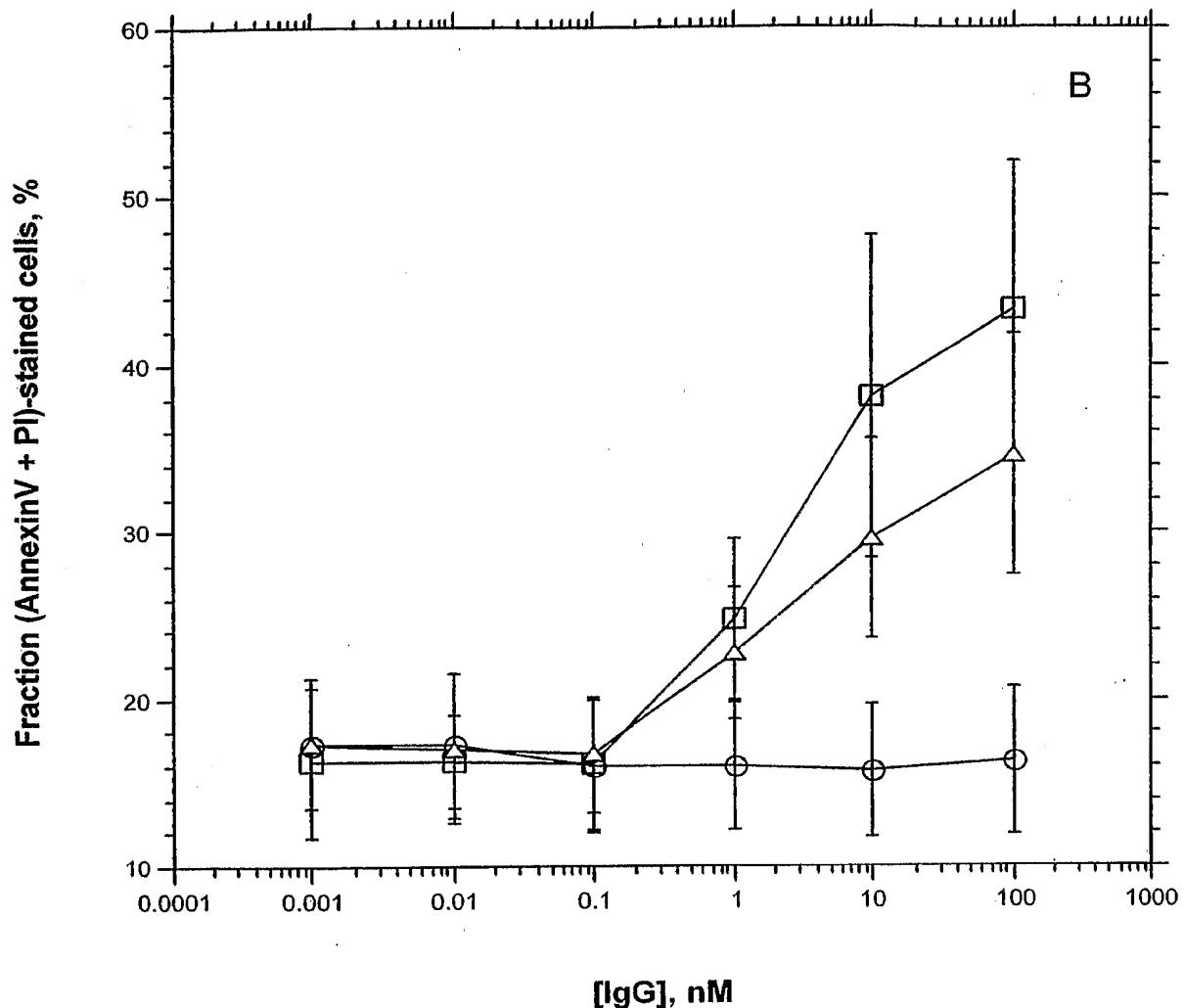


**FIG. 13**  
Apoptotic Activity: Annexin V Staining



**FIG. 14**

## Apoptotic Activity: Annexin V and Propidium Iodide Double-Staining



**FIG. 15**

## Apoptotic Activity: Live Unstained Cells

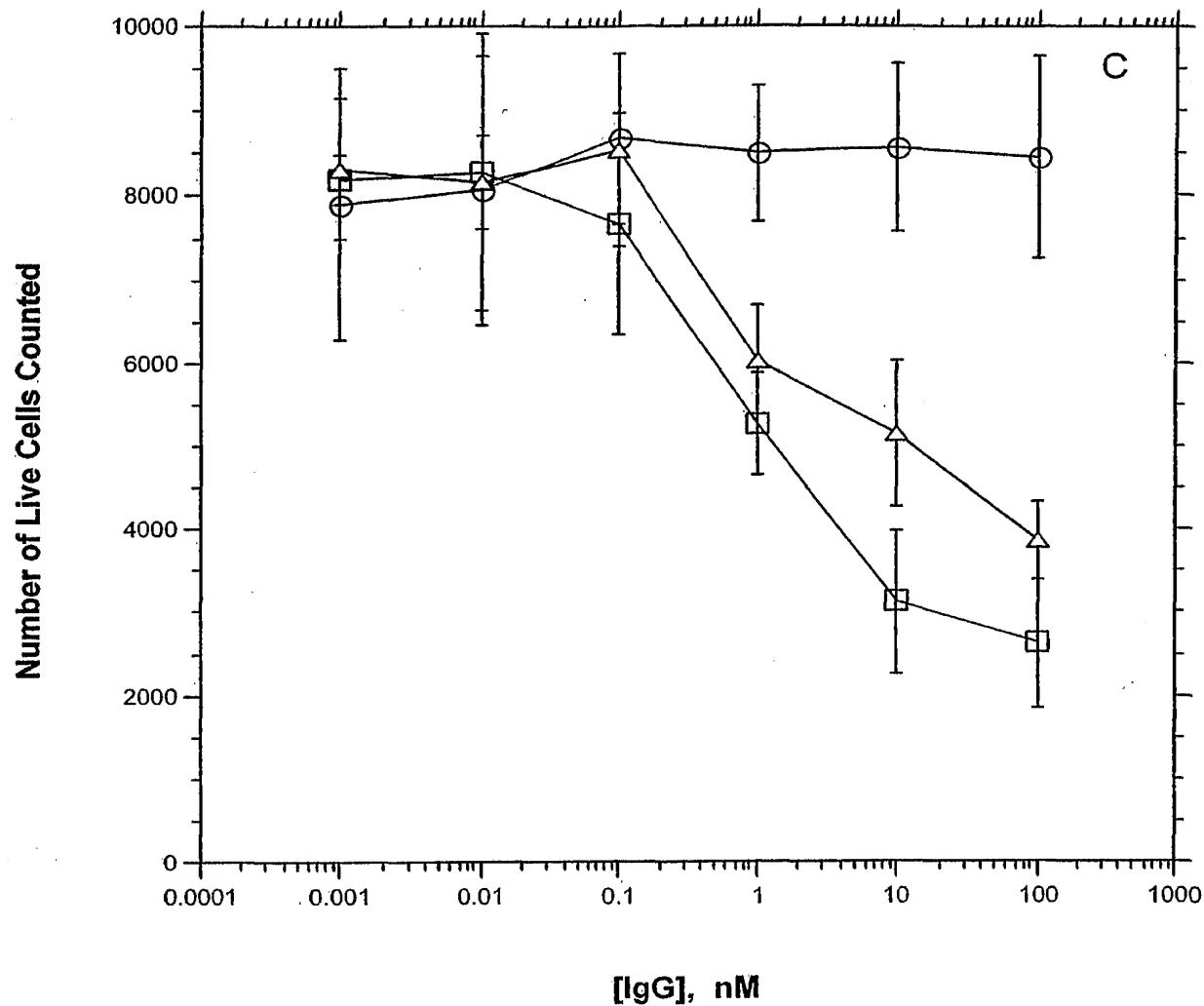
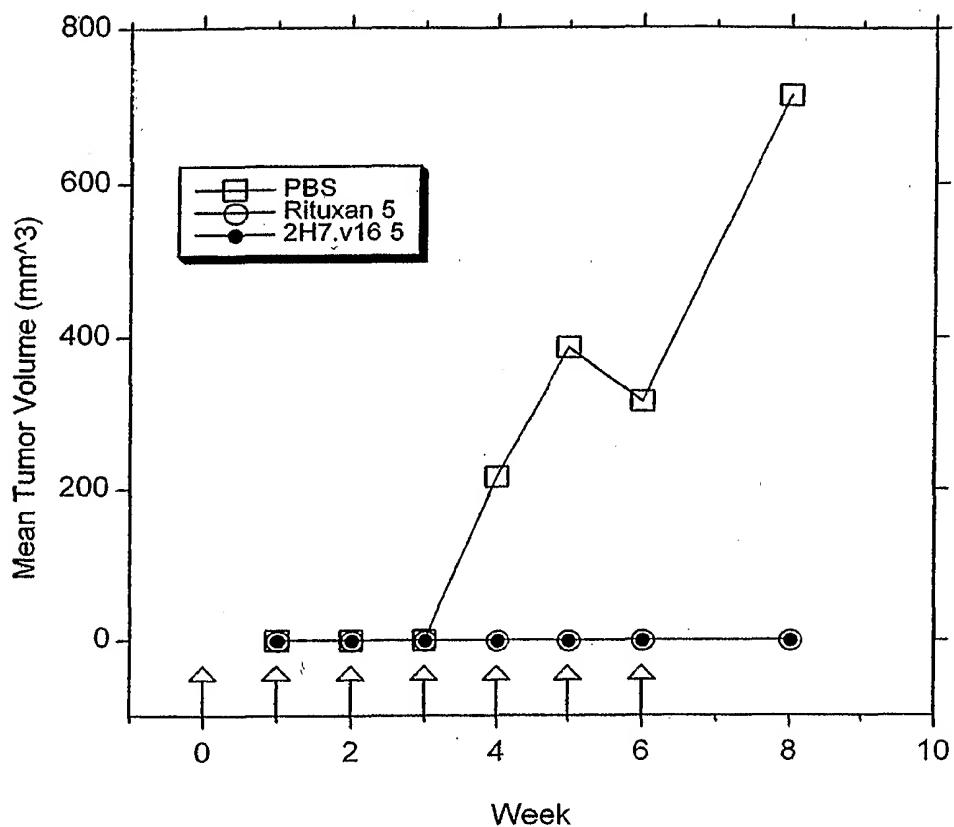


FIG. 16



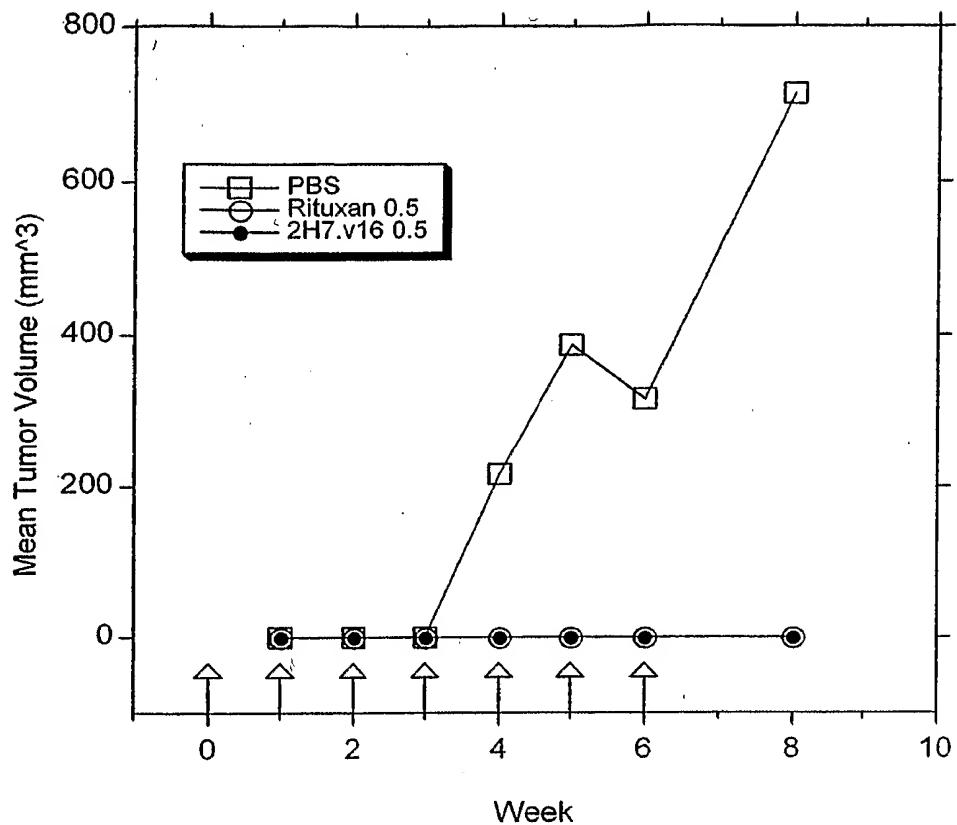
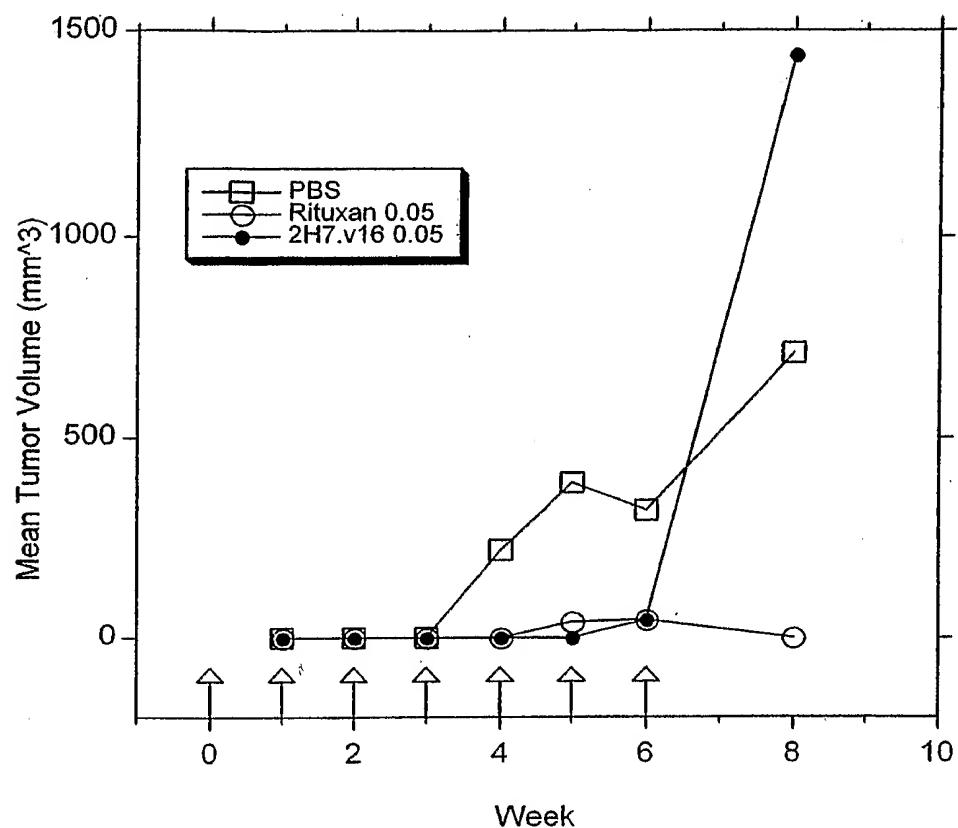
**FIG. 17**

FIG. 18

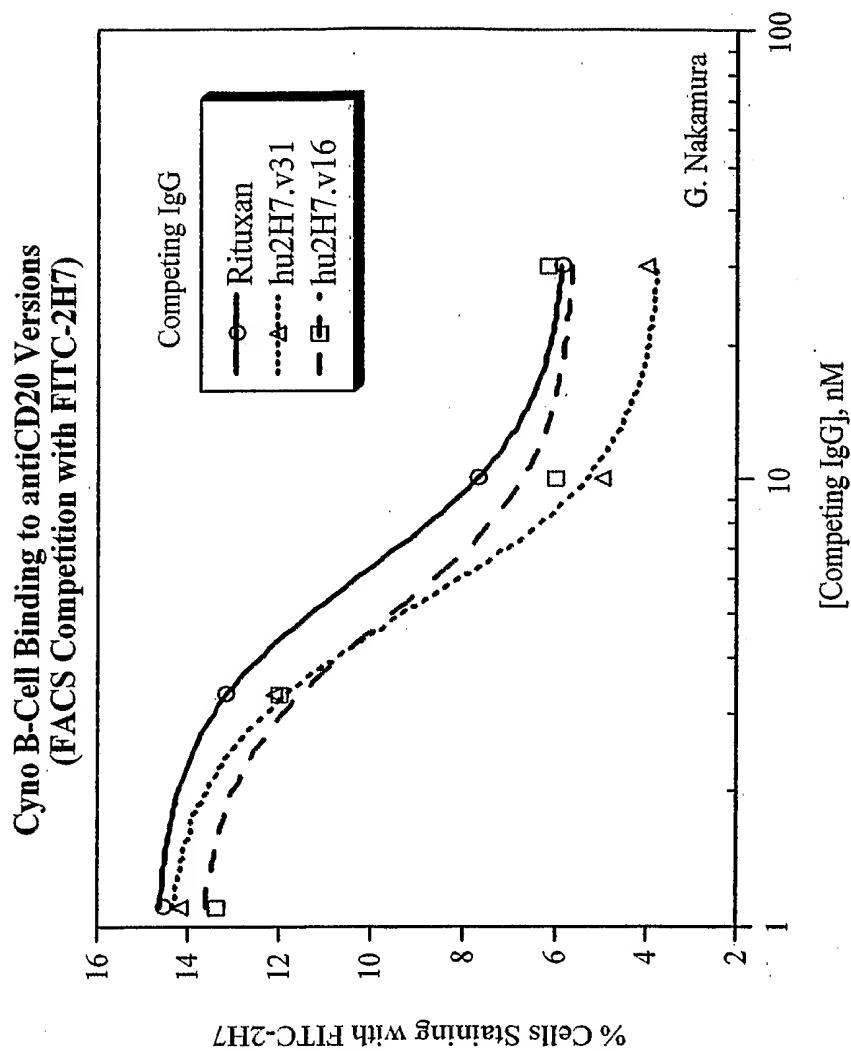


# FIG. 19

1 ATGACAAACAC CCAGAAATTC AGTAAATGGG ACTTTCCCAG  
 METThrThrPro ArgAsnSer ValAsnGly ThrPheProA  
 41 CAGAGCCAAT GAAAGGCCCT ATTGCTATGC AACCTGGTCC  
 1aGluProMET LysGlyPro IleAlaMETGln ProGlyPr  
 81 AAAACCACTC CTCAGGAGGA TGTCTTCACT GGTGGGTCCC  
 oLysProLeu LeuArgArgMET SerSerLeu ValGlyPro  
 121 ACGCAAAGCT TCTTCATGAG GGAATCTAAG GCTTTGGGGG  
 ThrGlnSerPhe PheMETArg GluSerLys AlaLeuGlyA  
 161 CTGTCCAGAT TATGAATGGG CTCTTCCACA TTGCCCTGGG  
 1aValGlnIle METAsnGly LeuPheHisIle AlaLeuGl  
 201 GGGTCTTCTG ATGATCCAG CAGGGATCTA TGCAACCATC  
 yGlyLeuLeu METIleProAla GlyIleTyr AlaProIle  
 241 TGTGTGACTG TGTGGTACCC TCTGTGGGA GGCATTATGT  
 CysValThrVal TrpTyrPro LeuTrpGly GlyIleMETT  
 281 ATATTATTTC CGGATCACTC CTGGCAGCAA CGGAGAAAAA  
 yrIleIleSer GlySerLeu LeuAlaAlaThr GluLysAs  
 321 CTCCAGGAAG TGTTTGGTCA AAGGAAAAAT GATAATGAAT  
 nSerArgLys CysLeuValLys GlyLysMET IleMETAsn  
 361 TCATTGAGCC TCTTTGCTGC CATTCTGGGA ATGATTCTTT  
 SerLeuSerLeu PheAlaAla IleSerGly METIleLeuS  
 401 CAATCATGGA CATACTTAAT ATTAAAATTT CCCATTTTT  
 erIleMETAsp IleLeuAsn IleLysIleSer HisPheLe  
 441 AAAAATGGAG AGTCTGAATT TTATCAGAGT TCACACACCA  
 uLysMETGlu SerLeuAsnPhe IleArgVal HisThrPro  
 481 TATATTAAACA TATACAACTG TGAACCAGCT AATCCCTCTG  
 TyrIleAsnIle TyrAsnCys GluProAla AsnProSerG  
 521 AGAAAAACTC TCCATCTACT CAATACTGTT ACAGCATACA  
 luLysAsnSer ProSerThr GlnTyrCysTyr SerIleGl  
 561 ATCTCTGTTCTGGCATTT TGTCACTGAT GCTGATCTTT  
 nSerLeuPhe LeuGlyIleLeu SerValMET LeuIlePhe  
 601 GCCTCTTCC AGGAACCTGT AATAGCTGGC ATCGTTGAGA  
 AlaPhePheGln GluLeuVal IleAlaGly IleValGluA  
 641 ATGAATGGAG AAGAACATGC TCCAGACCCA AATCTAGCGT  
 snGluTrpArg ArgThrCys SerArgProLys SerSerVa  
 681 AGTTCTCTG TCAGCTGAAG AAAAAGAG ACAAGTCATT  
 lValLeuLeu SerAlaGluGlu LysLysGlu GlnValIle  
 721 GAAATAAAAG AAGAAAGTGGT TGGGCTAACT GAAACATCTT  
 GluIleLysGlu GluValVal GlyLeuThr GluThrSerS  
 761 CCCAACCAAA GAATGAAGAA GCCATTGAAA TTATTCCAAT  
 erGlnProLys AsnGluGlu AlaaIleGluIle IleProII  
 801 CCAAGAAGAG GAAGAAGAAG AAACAGAGAC AAACATTCCA  
 eGlnGluGlu GluGluGluGlu ThrGluThr AsnPhePro  
 841 GAAACCTCCCC AAGATCAGGA ATCTTCACCA ATAGAAAATG  
 GluProProGln AspGlnGlu SerSerPro IleGluAsnA  
 881 ACAGCTCTCC T.  
 spSerSerPro

**FIG. 20**

MTTPRNSVNGTFPAEPMKGPIAMQPGPKPLLRRMSSLVGPTQSFFMR  
S F  
ESKALGAVQIMNGLFHIALGGLLMIPAGIYAPICVTWYPLWGGIMYII  
SGSLLAATEKNSRKCLVKGKMMNSLFAAISGMILSIMDILNIKISH  
**FLKMESLNFIRVHTPYININCEPANPSEKNSPSTQYCYSIQSLFLGILS**  
A  
VMLIAFFQELVIAGIVENEWRRTCSRKSSVULLSAEKKEQVIEIKE  
K NI T  
EVVGLTETSSQPKNEEAIEPIQEEEEETTENFPEPPDQESSPIENDS  
D  
SP

**FIG. 21**

**Fig. 22**

## Dose Escalation Schema

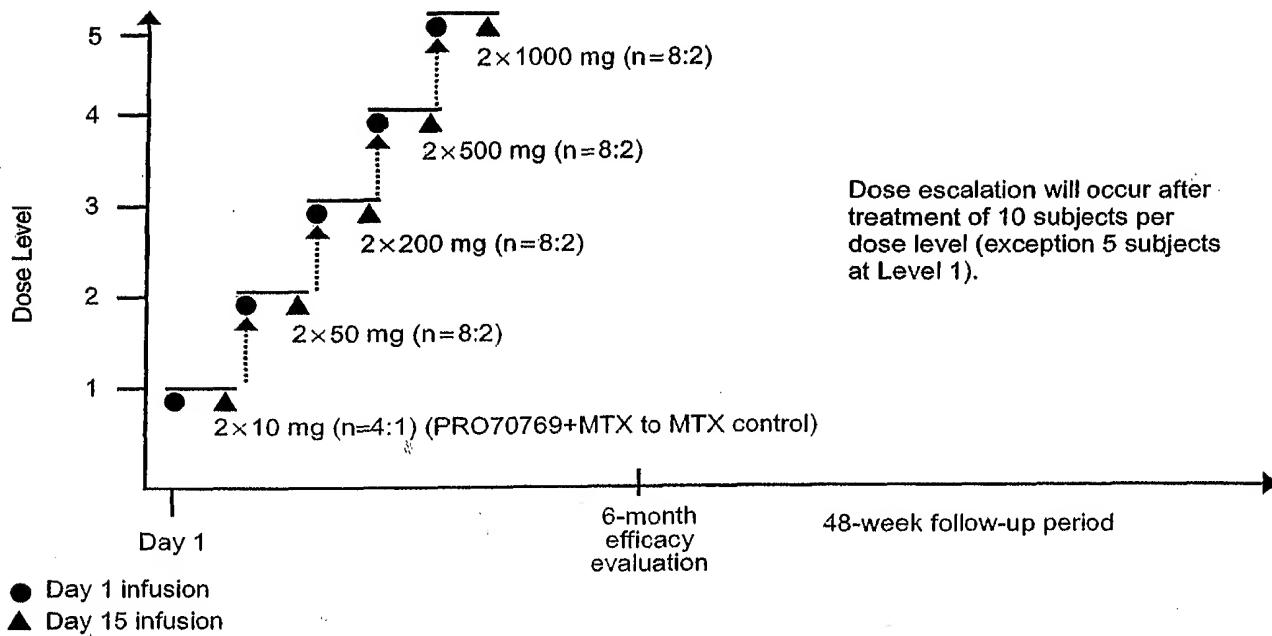


FIG. 23

SV40.PD.hu2H7.H16.SV.L16  
8.277 kb

